

DRAFT

**REMEDIAL INVESTIGATION/ FEASIBILITY STUDY
(RI/FS)
FIELD SAMPLING PLAN**

**SOUTH DAYTON DUMP & LANDFILL SITE
MORaine, OHIO**

JANUARY 2007

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APPENDIX J

FIELD SAMPLING PLAN

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J 1.0 INTRODUCTION

J 1.1 GENERAL

This Field Sampling Plan (FSP) was prepared for the South Dayton Dump and Landfill (Site) in Moraine, Ohio by Conestoga-Rovers & Associates (CRA). The purpose of this FSP is to outline the procedures to be used to perform the field activities associated with the Remedial Investigation/Feasibility Study (RI/FS) Work Plan. The RI tasks are discussed in Section 5.0 of the RI/FS Work Plan.

The RI is planned to be completed in phases, with the specific scope of Phase I defined in the Statement of Work (SOW) that is attached to the Administrative Settlement Agreement and Order on Consent (ASAOC). The FSP includes procedures for all items contemplated for the Phase I RI/FS. In addition, the FSP includes field sampling procedures that may be conducted as part of later phases of the RI.

J 1.2 ASSOCIATED DOCUMENTS

All activities discussed in this Field Sampling Plan will be performed in accordance with the Quality Assurance Project Plan and Health and Safety Plan (Appendices K and L, respectively, of the RI/FS Work Plan).

J 1.3 BASIS

This FSP was prepared in accordance with the SOW. The FSP defines and details the field sampling and data gathering activities required to collect the necessary data to complete the RI/FS at the Site. The SOW requires that the following work be completed during Phase I RI:

- Geophysical Survey;
- Land Survey;
- Geoprobe shallow groundwater investigation;
- Nine test trenches;
- Four test pits;
- Five new shallow groundwater monitoring wells;
- One shallow source area groundwater monitoring well;
- Three new deep groundwater monitoring wells;

- Two contingency deep groundwater monitoring wells;
- Three shallow piezometers;
- Up to 10 surface water gauges;
- Survey all new monitoring locations;
- Collection of one surface soil sample and one subsurface soil sample at each new monitoring well or probe location;
- Levee inspection;
- Collection of five soil samples for geotechnical analysis;
- Bathymetry Survey of the Quarry Pond;
- Install five landfill gas probes; and
- Wetlands delineation.

The FSP also includes procedures for other filed work (Section J 3.0) that may occur following completion of Phase I of the RI.

The sampling and data gathering procedures presented herein will augment the existing data available for the Site. Historic Site investigations and available Site data are presented in Section 2.0 of the RI/FS Work Plan. Historical soil sampling and borehole locations are presented on Figure J-1.1. The existing monitoring well network is presented on Figure J-1.2.

J 2.0 SAMPLING EQUIPMENT AND PROCEDURES

The following sections are presented in the order in which they were presented in Section 5.0 of the RI/FS Work Plan. The sections below present procedures for field tasks as follows:

Section J 2.1	Soil;
Section J 2.2	Groundwater;
Section J 2.3	Surface Water;
Section J 2.4	Sediment;
Section J 2.5	Landfill Gas Probes;
Section J 2.6	Seep Monitoring; and
Section J 2.8	Miscellaneous.

This FSP presents the procedures and methods that will be used to implement the field work. Phase I of the RI will be implemented in the following tentative sequence:

- Geophysical Survey;
- Install nine test trenches;
- Install four test pits;
- Conduct Geoprobe shallow groundwater investigation;
- Install three shallow piezometers;
- Install new shallow groundwater monitoring wells;
- Vertical aquifer sampling (VAS);
- Install three new deep groundwater monitoring wells;
- Install two contingency deep groundwater monitoring wells if necessary;
- Collection of five soil samples for geotechnical analysis;
- Collection of one surface soil sample and one subsurface soil sample at each new monitoring well or probe location;
- Install five landfill gas probes;
- Install 10 surface water gauges;
- Survey topography, all existing and new monitoring wells, all new and existing piezometer, surface water gauges and land fill gas probe locations;
- Groundwater and surface water sampling;

- Landfill gas sampling;
- Levee inspection;
- Seep inspection;
- Bathymetry Survey of the Quarry Pond; and
- Wetlands delineation.

J 2.1 SOIL

Soil sampling will be conducted at the Site to further characterized surface and subsurface materials and provide analytical data, which will be used to determine human health and ecological risks.

Soil will be characterized to determine chemical concentrations. One surface and one subsurface soil sample will be collected during installation of all proposed test pit, monitoring/piezometer well locations, surface water/sediment and soil gas probe locations. Proposed sample locations are shown on Figures J-2.1, J-2.2, J-2.3, and J-2.4, respectively.

Boreholes installed for the purpose of monitoring well construction and soil sampling will be advanced using 6 1/4-inch inside-diameter hollow-stem auger (HSA) drilling techniques (for 4-inch (10-cm) wells) or rotosonic drilling techniques (for boreholes designated for deep monitoring wells and soil sampling in the event that attempts to install these borings using HSA drilling techniques are unsuccessful).

Boreholes installed for soil gas probe will be advanced using 4 1/4-inch inside-diameter HSA drilling techniques (for 2-inch (5-cm) wells).

Each HSA borehole conducted for the purpose of soil sampling will be advanced to the water table. Soil samples will be collected using 2-inch split-spoon samplers in continuous 2-foot intervals. Borehole installation procedures for the rotosonic drilling technique are discussed in Section J 2.2.1.2.

All soil samples will be described using the Unified Soil Classification System (USCS) and will be screened using a photoionization detector (PID). Field calibration, preventative maintenance, and standard operating procedures (SOPs) for the PID are in Section 6.0.

The stratigraphic sequence observed at each borehole will be described on an Overburden Stratigraphy Log, an example of which is in Attachment J-A. Two samples will be collected for analysis from each borehole. One sample will be collected from the 0- to 2-foot below ground surface (bgs) interval, and one subsurface sample will be collected from depth exhibiting the highest field screening readings. Each sample will be submitted to a laboratory for analyses. Soil sample chemical analyses are summarized in Table J-2.1.

The samples collected and analyzed for volatile organic compounds (VOCs) will be completed in accordance with SW-846 Method 5035/8260B. Samples for VOC analyses will be collected first, using the En Core™ sampler, and collecting the sample volume from 18- to 24-inch bgs interval (in the case of a soil sample collected over the 0- to 2-foot bgs interval). Samples for VOC analysis will be collected using the disposable En Core™ sampler as follows:

- hold coring body and push plunger rod down until small o-ring rests against tabs. This will assure that plunger moves freely;
- depress locking lever on En Core™ T-Handle. Place coring body, plunger end first, into open end of T-Handle, aligning the 2 slots on the coring body with the 2 locking pins in the T-Handle. Twist coring body clockwise to lock pins in slots. Check to ensure sampler is locked in place. Sampler is ready for use;
- turn T-Handle with T-up and coring body down. This positions the plunger bottom flush with the bottom of the coring body (ensure that the plunger bottom is in position). Using the T-Handle, push sampler into soil until coring body is completely full. When full, small o-ring will be centered in T-Handle viewing hole. Remove sampler from soil. Wipe excess soil from coring body exterior;
- cap the coring body while it is still on the T-handle. Push and twist the cap over the bottom until grooves on locking arms seat over the ridge on the coring body. CAP MUST BE SEATED TO SEAL SAMPLER;
- remove the capped sampler by depressing the locking lever on the T-Handle while twisting and pulling the sample from the T-Handle;
- lock the plunger by rotating the extended plunger rod fully counter-clockwise until the wings rest firmly against the tabs;
- attach a completed circular label (from En Core™ sampler bag) to the cap on the coring body; and
- return the full En Core™ sampler to zipper bag.

Soil samples collected from HSA drill activities will be obtained by continuously using 2-inch diameter split-spoon samplers, using the techniques described in American Society for Testing and Materials (ASTM) Method D-1586 (ASTM Methods are contained in Attachment J-C). Soil samples will be classified using the USCS in accordance with ASTM Method D-2488 (ASTM Methods are contained in Attachment J-C) and stored in clear glass jars for future reference. The jars will be labeled with the CRA project number, the soil boring identification number, the depth sampled, and the date. All soil samples will be stored in accordance with Section J 5. Three samples will be selected for analysis from each borehole. One sample will be collected from the upper portion (i.e., 0 to 2 or 2 to 4 feet); one sample will be collected from immediately above the water table; and one will be collected in the middle portion. Additional soil sampling procedures are presented in Attachment J-B.

Quality Assurance/Quality Control (QA/QC) samples will be collected as discussed in Section J 4.0. Samples will be handled as discussed in Section J 5.0.

All locations will be surveyed as discussed in Section J 2.6.1.

All downhole equipment such as augers, drill rods, and split-spoon samplers will be decontaminated as discussed in Section J 7.0. Cuttings and decontamination water will be managed as discussed in Section J 8.0.

Soil samples will be submitted for grain size, fraction of organic carbon, plasticity index, porosity, permeability, and Atterburg limits.

J 2.1.1 TEST PITS/TEST TRENCHES

Test pits and test trenches are being install at the Site to visually identify and characterize subsurface materials and to determine the extent and nature of fill. Test pit and test trench location are presented on Figure J-2.1. Sampling and analysis of soils collected from the test pits and trenches will also allow for the determination of any direct contact, ingestion and migration exposure scenarios.

An excavator or backhoe will be used to excavate the test pits. The test pit excavation procedures are as follows:

1. Each test pit will be assigned a unique identification number. Prior to starting the test pit excavations, the locations of each test pit and trench will be staked in the field using the locations identified on Figure J-2.1.

2. The area immediately adjacent to the test pit will be covered with two layers of 6-mil polyethylene sheeting for stockpiling excavated waste and soil. The polyethylene sheeting and excavation spoils will be placed downwind of field personnel and in such a manner that water runoff from the waste material will be directed back into the excavation. If possible, soil/waste material temporarily stockpiled on the liners will be backfilled into open excavations before the contractor leaves the Site for the day. If the waste material cannot be backfilled at the end of the work day, the contractor will ensure the material is covered securely with a polyethylene liner, to control potential emissions and to minimize the exposure of the material to rainwater.
3. The test pits will be a minimum of 4 feet wide and will extend 4 feet below the bottom of the waste materials or to a maximum depth of 15 feet. The lengths of individual test pits will be determined in the field by the field representative based on conditions encountered during excavation. Excavation at each location will be completed in a controlled manner so as to minimize damage to any potentially intact drums.
4. Ten empty drum overpacks will be maintained at the Site during excavation. Should an intact waste container be damaged during excavation, it will be immediately removed from the excavation and placed in an overpack. Any material that becomes visibly impacted by a release from a damaged waste container will also be removed from the excavation and placed on a separate sheet of polyethylene adjacent to the test pit. All visibly impacted material will be transferred to one of the existing hazardous waste stockpiles and managed in accordance with procedures specified for those stockpiles. Should more than ten drums be encountered the test pit and trenching work will be abandoned until additional overpack drum can be obtained.
5. Each test pit will be backfilled with the excavated materials in reverse order to that in which they were removed. The test pit will be restored to match surface conditions prior to excavation.

Test trenches will be excavated in the same manner as test pits except that test trenches will be excavated in a continuous length of up to 30 feet. The test trenches will be used to determine the limits of the fill or confirm substantive changes in the nature and extent of the fill material.

J 2.1.2 TEST PITS AND TRENCH SAMPLING

The following sampling procedures and associated tasks will be performed as part of the test pit and test trench investigation.

1. A photographic log of each test pit excavation during its progression will be recorded. The photographic record will list the date of each photograph, a specific description of what the photograph depicts, its location, and the photographer.
2. The dimensions of excavation and a description of the soils encountered during excavation will be recorded on a Test Pit Stratigraphy log, an example of which is contained in Attachment J-A.
3. Markings on drums or other waste containers encountered will be examined, documented, and photographed and keyed to a unique drum identification number.
4. The contents of selected drums or other waste containers encountered will be sampled. The containers to be sampled will be selected by the field representative. Samples will be collected in or near test pits from containers that are ruptured and whose contents are readily accessible. Any number of waste containers may be sampled. Liquid samples will be analyzed for the parameters and with the methods specified in Table J-2.1.
5. Samples of the soil, will be collected, from each wall and the base of the excavation will be collected during the excavation. The specific soil selected for sampling and number of samples will be determined in the field by the field representative. Sample selection will be based on the visual appearance of the material (for example, color, staining, grain size), location of the soil prior to removal (for example, adjacent to drums or base of excavation), and field instrument measurements. The observations will be recorded in the Test Pit Stratigraphy log. The samples will be collected directly from the bucket of the excavator and/or the stockpiled spoils. The sample collection procedures will be the same as those specified in Section J 2.1.
6. In addition, a portion of each sample will be placed in a separate container for headspace analysis. Results of the headspace analysis will be recorded in the Test Pit Stratigraphy log. A representative soil sample from each distinct fill or waste type observed in each test pit and test trench will be retained to prepare a composite sample for each distinct fill or waste type excavation will be submitted for laboratory analysis for chemical parameters.

7. A composite sample of each distinct fill or waste type will be prepared in the laboratory Toxicity Characteristic Leaching Procedure (TCLP) with subsequent analysis of the leachate for VOCs, semi SVOCs and Metals. The parameters and associated analytical methods are specified in Table J-2.1.

J 2.2 GROUNDWATER

Section 2.0 in the Work Plan describes the regional and Site hydrogeology. The following hydrostaticgraphic units exist at the Site based on available information:

- Upper Aquifer Zone– glacio-fluvial sand and gravel facies;
- Till-Rich Zone – a zone of discontinuous low permeability till facies interspersed with sand and gravel facies; and
- Lower Aquifer Zone– consisting of glacio-fluvial sand and gravel facies.

The sections below present procedures for field tasks related to groundwater investigations:

- Section J 2.2.1 Monitoring Well Installation;
- Section J 2.2.2 Monitoring Well Development;
- Section J 2.2.3 Single-Well Response Testing;
- Section J 2.2.4 Hydraulic Monitoring; and
- Section J 2.2.5 Groundwater Sampling.

Groundwater monitoring wells, temporary monitoring wells and piezometers will be installed, monitored and/or sampled in order to characterize the Upper and Lower aquifer Zones at the Site and identify and impacts to these units arising from historical Site activities. In addition, the groundwater data will be used to determine any human health risks associated with exposure to Site groundwater. The specific rationale for well locations is presented in Sections 4.0 and 5.0 of the Work Plan and summarized below.

J 2.2.1 MONITORING WELL INSTALLATION

The proposed monitoring well locations are presented on Figure J-2.2. The locations of monitoring wells may be adjusted in the field, if necessary. A total of six shallow (MW101A-S, MW201S, MW210-S, MW213-S, MW214-S, and MW215-S) and three deep

monitoring wells (MW101A-D, MW201-D, and MW-210-D) are proposed to be installed at the Site during the Phase I RI/FS. The shallow monitoring wells are being installed in order to characterize shallow groundwater quality, characterize vertical groundwater migration, and provide data to assess the potential human health risks at the Site. The deep monitoring wells are being installed in order to characterize deep groundwater, vertical groundwater migration and provide data to assess the potential human health risks at the Site.

The specific rationale for each location is listed below.

<i>Proposed Location</i>	<i>Description</i>	<i>Rationale</i>
MW-101A-S	Upper Aquifer Zone groundwater monitoring well	Fill data gap at water table interface
MW-101A-D	Lower Aquifer Zone groundwater monitoring well, vertical profiling	Characterize Lower Aquifer Zone groundwater quality
MW-210-S	Upper Aquifer Zone groundwater monitoring well	Fill data gap at water table interface
MW210-D	Deep groundwater monitoring well, vertical profiling	Characterize Lower Aquifer Zone groundwater quality
MW-201-S	Upper Aquifer Zone groundwater monitoring well	Fill data gap at water table interface
MW-201-D	Deep groundwater monitoring well, vertical profiling	Characterize Lower Aquifer Zone groundwater quality
MW-213-S	Upper Aquifer Zone groundwater monitoring well, vertical profiling	Characterize downgradient Upper Aquifer Zone groundwater quality
MW-214-S	Upper Aquifer Zone groundwater monitoring well, vertical profiling	Characterize downgradient Upper Aquifer Zone groundwater quality
MW-215-S	Upper Aquifer Zone groundwater monitoring well	Source area well

The RI includes two rounds of groundwater quality monitoring at all new and existing wells, periodic synoptic groundwater and surface water elevation measurements and slug tests on all new monitoring wells.

In addition, at each new monitoring well location installed on Site, CRA will collect one surface and one subsurface soil sample during the installation of the soil boring at that location and submit for chemical analyses.

During installation of each deep monitoring well, VAS will be conducted to determine the vertical extent of contamination and to identify the appropriate well screen interval for deep wells. VAS samples will be collected at 5-foot intervals beginning 5 feet below the static water level encountered in the adjacent shallow monitoring well. VAS will be performed to a maximum depth of 100 feet bgs at all locations. VAS samples will be analyzed for TCL VOCs on an expedited turnaround time. The well screen interval for deep wells will be selected to coincide with the zone of highest contamination observed in the VAS samples collected at each boring. Monitoring wells will be completed with 5-foot long, 2-inch diameter, 0.010-inch slot well PVC screens attached to a suitable length of 2-inch diameter flush-threaded riser pipe. The primary filter pack for the monitoring wells will consist of 10 to 20 mesh silica sand. Procedures for VAS and monitoring well installation are provided in Section J 2.0 of the FSP..

Two new deep monitoring wells will be installed at MW-213-S and at MW-214-S should the results of the VAS at those locations indicate the presence of contamination in the Lower Aquifer zone at either location. These deeper wells will complement the new shallow wells by completing a nested pair.

The first round of on-Site groundwater sampling and hydraulic monitoring will be conducted on all four existing monitoring wells and the proposed five shallow wells and seven deep wells discussed above. Groundwater samples will be analyzed for TCL VOCs, TAL SVOCs, TAL Inorganics, PCBs, and field parameters as identified in Table J 2.2. Natural attenuation parameters may be added to subsequent rounds of analyses if the VOCs and SVOCs data suggest it appropriate.

All monitoring wells will be developed prior to sampling, and will be subject to single-well response testing. Procedures for well development and single-well response testing are provided below.

The shallow monitoring wells (screened at approximately 25 to 30 feet bgs) and deep monitoring wells (screened at approximately 45 to 50 feet bgs) will be installed using the 6 1/4-inch inside-diameter HSA method. In the event that attempts to install the boreholes for construction of the deep monitoring wells using HSA drilling techniques are unsuccessful, the deep monitoring wells will be installed using the rotosonic method using a nominal 10-inch diameter casing. A monitoring well construction detail is

shown on Figure J-2.5. All monitoring wells will be surveyed in accordance with Section J 2.7.1.

All downhole equipment such as augers, drill casings, drill rods, and split-spoon samplers will be decontaminated as discussed in Section J 7.0. Drill cuttings and decontamination water will be managed as discussed in Section J 8.0.

The monitoring wells will be constructed of 2-inch, 0.01-inch (10 slot), 5-foot long slotted PVC screens with threaded end caps. Monitoring well risers will be 2-inch diameter PVC with flush-threaded joints.

Shallow monitoring well installation is discussed in Section J 2.2.1.1. Deep monitoring well installation is discussed in Section J 2.2.1.2.

J 2.2.1.1 SHALLOW MONITORING WELL INSTALLATION

Borings will be advanced using 6 1/4-inch inside diameter HSA drilling techniques with continuous split-spoon sampling. Soil samples will be collected continuously using 2-inch diameter split-spoon samplers, using the techniques described in ASTM Method D-1586. Soil samples will be classified using the USCS in accordance with ASTM Method D-2488 (ASTM Methods are in Attachment J-C). The stratigraphic sequence observed at each borehole will be described on an Overburden Stratigraphy Log, an example of which is in Attachment J-A.

Augers are available with inside diameters of 2.5, 3.25, 4.0, 4.25, 6.25, 8.25, and 10.25 inches. The most commonly used are 4.25 inches for 2-inch (5 cm) monitoring wells and 6.25 inches for 4-inch (10 cm) monitoring wells. Removing augers in flowing sand conditions while installing monitoring wells may be difficult since the augers have to be removed without being rotated. A bottom plug or pilot bit assembly should be utilized to keep out soils and/or water that have a tendency to plug the bottom of the augers during drilling. If flowing sands are encountered, potable water (analyzed once for VOCs, TCL SVOCs and Target Analyte List Inorganics) may be poured into the augers to equalize the pressure to keep the formation materials and water from coming up into the auger once the bottom plug is removed.

The well screen and riser will be installed through the hollow-stem augers, which will provide a minimum of 2 inches clearance on all sides of the casing. A tremie pipe will be used to place a filter pack consisting of coarse silica sand (10-20 mesh) from the bottom of the well screen to 2 feet above the well screen, and 1 foot of fine (20-40 mesh)

silica sand from 2 to 3 feet above the well screen. Approximately 2 to 3 feet of bentonite gravel will be placed above the filter sand to help provide a seal for the bentonite grout.

The boring annulus above the bentonite gravel layer will be backfilled with bentonite grout to within 3 feet of ground surface. A tremie pipe will be used to emplace the backfill material below the water table or to depths greater than 20 feet bgs.

The uppermost 3 feet of the boring annulus will be filled with concrete, forming a pad of at least 2-foot diameter at ground surface, that slopes away from the well. A locking protective steel casing will be set in the concrete over the well riser. The well casing will extend to approximately 2.5 feet above ground surface, and will be fitted with a hinged cap. The well identification number will be permanently marked on the outer casing of all newly installed and existing monitoring wells.

J 2.2.1.2 DEEP MONITORING WELL INSTALLATION

The deep monitoring wells (screened at approximately 45 to 50 feet bgs) will be installed using the 6 1/4-inch inside-diameter HSA method or the rotosonic drilling method using a nominal 10-inch inside-diameter casing (in the event that attempts to install the boreholes for construction of the deep monitoring wells using HSA drilling techniques are unsuccessful).

Vertical aquifer sampling (VAS) will be conducted during advancement of the boreholes for construction of the deep monitoring wells. The purpose of the VAS is to determine the current presence or absence of impacted groundwater within the sand and gravel units and to aid in the selection of the screened intervals for the deep monitoring wells.

During the installation of deep monitoring wells, one soil sample from each distinct stratigraphic unit in the unsaturated zone will be collected from each borehole. Samples will be analyzed for the soil physical property parameters shown in Table J-2.1.

The HSA lower aquifer monitoring well installation and VAS procedure is as follows:

1. The HSA drill rig will advance a 6 1/4-inch inside diameter hollow-stem auger. The lead auger will be a slotted auger. Soil samples will be collected continuously using 2-inch diameter split-spoon samplers using the techniques described in ASTM Method D-2488 (ASTM Methods are in Attachment J-C). The stratigraphic sequence observed at each borehole will be described on an Overburden Stratigraphy Log, an example of which is in Attachment J-A.

2. The HSA borehole will be advanced from ground surface to a total depth of up to 80 feet bgs at all locations.
3. VAS will be conducted at 10-foot intervals beginning no deeper than 5 feet below the bottom of the screened interval of the adjacent shallow monitoring well. The water table position in each borehole will be determined through the visual examination of split-spoon soil samples for saturated conditions and the measurement of water levels within the hollow-stem augers.

Groundwater samples will be collected by means of a Grundfos (or equivalent) submersible pump. The pump assembly would consist of the pump and an inflatable packer attached to stainless steel riser pipe. The purpose of the packer is to isolate the lead-slot auger from the water column above it. The pump/packer assembly will be lowered into the annulus of the hollow-stem augers such that the pump is near the mid-point of the lead auger with the packer at the top of the lead-slot auger. At each sample interval, approximately three to five lead-slot auger volumes of groundwater will be purged prior to sample collection (the slotted auger volume is approximately 4 gallons). The number of auger volumes purged will be determined by comparing the results of the field parameters after each volume. The groundwater will be considered stable after a maximum of five auger volumes are removed or when three successive readings for pH, specific conductance, and temperature agree within the following limits:

pH	±0.1 pH unit
Specific conductance	±10 µmhos (temperature corrected)
Temperature	±1.0°C

Following the completion of purging of each sample interval, the pump flow rate will be reduced to the lowest sustainable flow rate.

4. The groundwater sample for each interval will be collected directly from the pump discharge into the sample containers. VAS samples will be analyzed for TCL VOCs on an expedited turnaround time. QC samples will be collected for chemical analysis as discussed in Section J 2.2.5. Samples will be handled as discussed in Section J 5.0.
5. Following the collection of each groundwater sample, the pump/packer assembly will be removed from the annulus of the hollow-stem augers. The pump/packer assembly will be decontaminated between samples following the procedures in Section J 7.0.
6. The screened interval for the monitoring well will be selected based on the results of the VAS sampling. The boring annulus below the screened interval

will be backfilled with bentonite gravel. A tremie pipe will be used to emplace the backfill material below the water table or to depths greater than 20 feet bgs. The monitoring well screen and riser pipe, silica sand filter pack, and bentonite grout will be installed.

7. After installing the well screen and riser, the hollow-stem augers will be removed from the borehole.

The roto sonic lower aquifer monitoring well installation and VAS procedure is as follows:

1. The roto sonic drill rig will advance a 4-inch diameter (nominal) core barrel for sampling and will also advance a 10-inch diameter outer casing for the construction of the monitoring wells.
2. The roto sonic borehole will be advanced from ground surface to a total depth of up to 75 feet bgs. The nominal 4-inch core barrel is advanced from 10 to 20 feet ahead of the nominal 10-inch diameter outer casing without the use of drilling fluids or air. The outer casing is then advanced to a depth of 10 feet less than the depth of the core barrel injecting some water to maintain a fluid head. The core sample is then retrieved from the inner core barrel.
3. Core samples will be taken directly from the core barrel attached to the end of the drill string and extruded into 10-foot long cylindrical bags. Field measurements for VOCs will be conducted along the cored material by piercing the plastic sleeve with the wand of the PID. Field calibration, preventative maintenance, and SOPs for the PID are contained in Section J 6.0.
4. A representative soil sample from each lithology in each core will be collected and classified using the USCS in accordance with ASTM Method D-2488 (ASTM Methods are in Attachment J-C). Each core will be described on an Overburden Stratigraphy Log, an example of which is in Attachment J-A.
5. VAS will be conducted at 10-foot intervals beginning no deeper than 5 feet below the bottom of the screened interval of the adjacent shallow monitoring well. The interval for groundwater sampling will be selected based on the review of the extracted core. A groundwater sampling assembly (2-inch temporary stainless steel well screen and 2-inch stainless steel riser pipe) will be installed to the required depth. An inflatable packer will be attached to the top of the screen to seal the inside of the 10-inch diameter outer casing from the formation. If necessary due to borehole collapse, the temporary well will be pushed and/or vibrated to the required depth.

6. A Grundfos or equivalent 2-inch diameter submersible pump attached to 1/2-inch diameter polyethylene tubing will be installed into the temporary well and set within the temporary well screen.
7. Three to five well volumes will be purged prior to sample collection (one well volume equals the total volume of water in the temporary well screen and riser). The water level will be measured within the temporary riser pipe, using a Solinst Model 101 electric water level indicator or equivalent, in order to determine the well volume. The depth to the bottom of the screen will be known.
8. Water samples will be collected and checked following each purged well volume for field measured parameters in order to show stability. The number of well volumes purged will be determined by comparing the results of the field parameters after each well volume. The groundwater will be considered stable after a maximum of five well volumes are removed or when three successive readings for pH, specific conductance, and temperature agree with the following limits:

pH	±0.1 pH unit.
Specific conductance	±10 µmhos (temperature corrected).
Temperature	±1.0°C.
9. Upon purging of the required well volumes, the flow rate will be reduced to the lowest sustainable flow rate and sampling will be conducted after purging at least one sample tubing volume (1/2-inch tubing volume is 0.010 gal/foot).
10. The groundwater sample for each interval will be collected directly from the pump discharge into the sample containers. VAS samples will be analyzed for TCL VOCs on an expedited turnaround time. QC samples will be collected for chemical analysis as discussed in Section J 2.2.5. Samples will be handled as discussed in Section J 5.0.
11. The temporary well will be removed and the borehole will be extended an additional 10 feet. The temporary well materials will be decontaminated between samples following the procedures outlined in Section J 7.0.
12. The screened interval for the monitoring well will be selected based on the results of the VAS sampling. The boring annulus below the screened interval will be backfilled with bentonite gravel. A tremie pipe will be used to emplace the backfill material below the water table or to depths greater than 20 feet bgs. The monitoring well screen and riser pipe, silica sand filter pack, and bentonite grout will be installed.
13. After installing the well screen and riser, the outer casing will be removed from the borehole.

The deep monitoring wells will be constructed as described for the shallow monitoring wells.

J 2.2.1.3 SHALLOW PIEZOMETER /TEMPORARY WELL INSTALLATIONS

The proposed piezometer and temporary well locations are presented on Figure J-2.2. The locations of wells may be adjusted in the field, if necessary. A total of three (P-216, P-217 and P-218) piezometer and five temporary wells are proposed to be installed at the Site during the Phase I RI/FS. The piezometer wells are being installed in order verify groundwater flow direction and aquifer response in the Upper Aquifer. The temporary wells are being installed in the southern portion of the Site adjacent to residential properties which are potentially downgradient from the Site with regards groundwater flow. The temporary wells are being installed in order verify groundwater flow direction, aquifer response in the upper aquifer, characterize potential groundwater impacts and determine human health and ecological risks to exposure of shallow groundwater. The specific rationale for each piezometer well location is listed below.

<i>Proposed Location</i>	<i>Description</i>	<i>Rationale</i>
P-216	Shallow groundwater piezometer well	Fill data gap and provide additional hydrogeological information
P-217	Shallow groundwater piezometer well	Fill data gap and provide additional hydrogeological information
P-218	Shallow groundwater piezometer well	Fill data gap and provide additional hydrogeological information

Temporary well locations have been selected in order to further characterize shallow groundwater which is potentially migrating off-Site and to determine the human health risks associated with exposure to shallow groundwater.

The shallow piezometer and temporary wells will be installed using a 50-millimeter (mm) (2-inch) diameter Geoprobe dual-tube direct push technique to minimize formation disturbance. The borehole for the each piezometer well will be advanced to a target depth corresponding to the top of the upper aquifer or approximately 25 feet bgs. The piezometer wells will be completed using 13-mm (0.5-inch) diameter schedule 40 PVC continuous piping (i.e., no joints) with a screened

interval length of 0.3 meters. The void space between the screened interval and formation will be filled with No. 3 silica sand (i.e., sand pack) to approximately 0.2 meter above the top of the screened interval. Hydrated bentonite benseal will be placed on top of the sand pack to just below ground surface. The sand pack and benseal will be placed as the Geoprobe was withdrawn to ensure that the formation does not collapse around the screened interval or riser. A lockable surface casing will be set in concrete at ground surface around piezometer well. Typical piezometer wells completion details are summarized on Figure J-2.6. The soil piezometer well stratigraphic and instrumentation logs are presented in Appendix J-A. The piezometer wells locations are presented on Figure J-2.2.

J 2.2.2 MONITORING WELL DEVELOPMENT

All of the newly-installed monitoring wells will be developed by pumping or bailing, not sooner than 48 hours after grouting is completed. In addition, all existing wells will be redeveloped prior to groundwater sampling. Mild surging will be used if necessary. A submersible pump may also be used to develop the wells by raising and lowering the pump intake throughout the screened interval. Other well development methods such as air-lift pumping, air surging, and backwashing are unsuitable for the development of small diameter wells. Development will continue until the turbidity of the development water is equal to or less than 5 nephelometric turbidity units (NTUs). In the event that turbidity values of less than 5 NTUs cannot be achieved, well development may also be considered complete if all of the following conditions are met:

1. a minimum of ten well volumes have been removed in addition to any volume of water or fluid that was introduced into the well and/or formation during construction and development; and
2. temperature, pH, and conductivity have stabilized to plus or minus 10 percent over a minimum of at least three well volumes.

Turbidity will be measured using an HF Scientific DRT-15C Turbidimeter. Temperature, pH, and conductivity will be measured using a YSI Model 3560 instrument. Alternatively, equivalent instruments may be used. Field calibration, preventative maintenance, and SOPs are contained in Section J 5.0. Decontamination procedures for the surge block and submersible pump are contained in Section J 7.0. Decontamination fluids and purge water will be managed as described in Section J 8.0.

Development data will be recorded on a Well Development and Stabilization Form, an example of which is in Attachment J-A. Groundwater sampling will not proceed until at least 2 weeks after the completion of well development.

J 2.2.3 SINGLE-WELL RESPONSE TESTING

Single-well response (slug) testing will be performed at all newly installed and developed monitoring wells. Single well response testing will allow for the determination of aquifer response for both the Upper and Lower aquifer zones at the Site.

Single-well response testing will involve displacement of the water in the wells by inserting or removing a known volume ("slug"). The slug will consist of a section of solid PVC rod of known volume. The slug will be raised and lowered using nylon rope. New rope will be used at each well.

Prior to slug testing, the static water level in the well will be measured using a Solinst Model 101 water level meter, or equivalent, and a continuous recording transducer and datalogger system will be installed in the well. Field calibration, preventative maintenance, and SOPs are provided in Section J 6.0. The slug will then be quickly lowered into the water column, displacing a known volume of water and raising the water instantaneously. The decrease in the water level (falling head test) will be monitored continuously by the datalogger. The falling head test data will be discarded for wells where the static water level is below the top of the screen. The groundwater table lies below the top of the screen in such wells and, as a result, the water in the gravel pack should drain quickly into the adjacent sand and gravel above the saturated zone. The flow of water is not immediately controlled by the saturated portion of the aquifer in this situation giving non-representative values.

Once the water level returns to static conditions, the slug will be quickly removed from the well, instantaneously dropping the water level. The increasing water level (rising head test) will be monitored continuously until the water level returns to static conditions.

Upon completion of the slug testing, the water level data will be used to calculate an estimated hydraulic conductivity using the method developed by Cooper et al. (1967), Bouwer and Rice (1976, Revised 1986), or Hvorslev (1951), depending on the aquifer condition (i.e., confined or unconfined). The slug will be decontaminated according to

procedures in Section J 7.0. Decontamination fluids will be managed as discussed in Section J 8.0.

J 2.2.4 HYDRAULIC MONITORING

Monitoring Wells

Hydraulic monitoring will be performed at all monitoring wells at the time of each groundwater sampling event. A minimum of two groundwater sampling events are planned. All hydraulic monitoring data will be collected within a 24-hour period for each monitoring event.

Water elevation measurements will be collected using a Solinst Model 101 water level indicator, or equivalent, and a reference point of known elevation on the monitoring well casing to determine the distance between the reference point and the water level in the well. The water level indicator is a battery-powered, self-contained instrument equipped with a cable and sensor that activates a buzzer and a light when it comes in contact with the water. The depth to water is read from permanent 0.01-foot increment markings on the cable. The reference point will consist of an indelible mark on the highest point of the well casing. All measurements will be recorded in a field logbook. Field calibration, preventative maintenance, and SOPs are contained in Section J 6.0.

The water level indicator will be decontaminated as discussed in Section J 7.0. Decontamination water will be managed as discussed in Section J 8.0.

Great Miami River elevation data will be obtained from 3 locations including a surveyed point on the Dryden Road bridge, a pond gauge installed at small pond, a pond gauge installed at large pond and a pond gauge installed at quarry pond. The surface water gauge will consist of a graduated rod driven to the river sediments and calibrated by a survey. Details on surface water gauge installation and monitoring are presented in Section J 2.3.

J 2.2.5 GROUNDWATER SAMPLING

Monitoring wells to be sampled include the 15 existing wells, all proposed wells and the two supply wells located on the Valley Asphalt property (Lot 5054).

The protocol described herein applies minimal drawdown techniques to obtain samples that are representative of groundwater moving through the subsurface under natural conditions. Groundwater samples will be collected and analyzed for the parameters listed in Table J-2.2.

All downhole equipment, such as the water level indicator, dissolved oxygen probe, and pumps, will be decontaminated as discussed in Section J 7.0. Purge water and decontamination water will be managed as discussed in Section J 8.0.

The minimal drawdown purging and sampling protocol will be as follows:

1. The groundwater level will be measured to the nearest 0.01 foot using a pre-cleaned Solinst Model 101 electric water level indicator or equivalent. Field calibration, preventative maintenance, and SOPs are contained in Section J 5.0.
2. The total depth of the monitoring well from the reference point (i.e., top of casing) will be measured to ± 0.01 foot using a pre-cleaned weighted measuring tape, such as a water level plopper. The measured well depth will be compared to the constructed well depth to evaluate the presence of any sediment accumulated at the well bottom. The use of a wide-based measurement device, such as a water level plopper, may minimize penetration of any sediment, thus facilitating a reliable measurement. The measurement device will be lowered slowly to the well bottom to minimize mixing of the stagnant well casing water and to minimize agitation of solids into suspension. The depth of any well bottom sediment will be considered when positioning the pump intake to avoid mobilizing the sediment while purging.
3. Purging will be conducted using a pre-cleaned stainless-steel bladder pump with a Teflon® bladder. The pump discharge line and air supply line for the bladder pump operation will be polyethylene and dedicated to the well. The bladder pump will be secured to nylon rope (dedicated to the well) and positioned in the well at least 24 hours prior to commencement of purging and sampling activities. The bladder pump will be positioned such that the pump intake corresponds to the middle of the screen.
4. Purging of the monitoring well will be conducted using a pumping rate, designed to minimize drawdown, no greater than 500 milliliters per minute (mL/min). Initial purging will begin using a pumping rate at the lower end of this range. The groundwater level will be measured while purging to ensure that less than 0.3 foot of drawdown occurs. The pumping rate may be gradually changed depending upon the amount of drawdown and the behavior of the stabilization parameters (see item 5 below). Pumping rate adjustments generally

will be made within 15 minutes from the start of purging and then should remain constant for the duration of purging. While purging, the pumping rate and groundwater level will be measured and recorded every 10 minutes (or as appropriate). If it is apparent that stabilization of the purged groundwater (see item 5 below) will not be achieved rapidly, these measurements may be made at longer time intervals to allow field staff to perform other sampling activities.

5. Stabilization of the purged groundwater is necessary prior to sampling to ensure that the samples obtained are representative of groundwater in the subsurface only and not influenced by stagnant groundwater stored in the well casing. The field parameters pH, temperature, conductivity, oxidation-reduction (redox) reaction potential (ORP), dissolved oxygen (DO), and turbidity will be monitored while purging to evaluate the stabilization of the purged groundwater. The field parameters will be measured and recorded every 10 minutes (or as appropriate) using the Monitoring Well Purging Record form, an example of which is in Attachment J-A. Stabilization will be considered to be achieved when three consecutive readings for each parameter are within the following limits:

pH	±0.1 pH units of the average value of the three readings;
temperature	±3 percent of the average value of the three readings;
conductivity	±0.005 milliSiemen per centimeter (mS/cm) of the average value of the three readings for conductivity <1 mS/cm and ±0.01 mS/cm of the average value of the three readings for conductivity >1 mS/cm;
ORP	±10 millivolts (mV) of the average value of the three readings;
DO	±10 percent of the average value of the three readings; and
turbidity	±10 percent of the average value of the three readings, or a final value of less than 5 nephelometric turbidity units (NTU).

pH, conductivity, temperature, and ORP will be monitored using a YSI Model 3560 instrument. Turbidity will be measured using an HF Scientific DRT-15C Turbidimeter. Dissolved oxygen will be measured using a YSI Model 52 instrument. Alternatively, equivalent instruments may be used. Field calibration, preventative maintenance, and SOPs are contained in Section J 5.0. At the start of purging, the purge water will be visually inspected for water clarity prior to connecting the flow-through-cell. If the purge water appears turbid, purging will be continued until the purge water becomes visibly less turbid before connecting the flow-through-cell. While purging, the meter readings will be monitored for evidence of meter malfunction. The following are common indicators of meter malfunctions:

- DO above solubility [e.g., oxygen solubility is approximately 11 milligrams per liter (mg/L) at 10° Celsius] may indicate a DO meter malfunction;
- negative ORP and DO greater than 1 to 2 mg/L may indicate either an ORP or a DO meter malfunction (i.e., should have positive ORP and DO greater than 1 to 2 mg/L under oxidizing conditions); and
- positive ORP and DO less than 1 mg/L may indicate either an ORP or a DO meter malfunction (i.e., should have negative ORP and DO less than 1 mg/L under reducing conditions).

Meter calibration fluids will be available for meter re-calibration in the field, if necessary.

In general, stabilization of the individual field parameters is expected to occur in the order listed above. Should stabilization not be achieved for all field parameters, purging will be continued until a maximum of 10 well screen volumes have been purged from the well. After purging 10 well screen volumes, purging will be continued if the purge water remains visibly turbid and appears to be clearing, or if stabilization parameters are varying slightly outside of the stabilization criteria listed above and appear to be approaching stabilization. In the event the monitoring well does not stabilize after the removal of 10 well screen volumes, the monitoring well will be redeveloped using the procedures described in Section J 2.2.2.

In the event that the groundwater recharge to the monitoring well is insufficient to conduct the minimal drawdown protocol, the well will be pumped dry and allowed to sufficiently recharge prior to sampling. Wells which are purged dry will not be subject to the above purging criteria.

Groundwater Sampling

Following purging and stabilization, groundwater sampling will be conducted using the following procedures:

- i) A new pair of disposable latex gloves will be used for each sample collected.
- ii) The flow-through-cell will be disconnected prior to obtaining the sample. The discharge line from the pump will be positioned at the base of the sample bottle. All required preservatives will be added to the samples in the manner consistent with the appropriate methodology by either placing the preservative in the sample containers prior to sampling or adding at the sample location immediately after collection. The sample bottle will be filled from the bottom to the top and will be allowed to overflow before sealing (over flow is not recommended if the sample

bottles have been prepared with preservatives prior to sample collection). Samples will be collected in the following order:

- a) VOCs;
- b) Semivolatile organic compounds (SVOCs), polychlorinated biphenyls (PCB)s;
- c) unfiltered inorganics and general chemistry; and
- d) filtered inorganics.

Each VOC sample vial will be inspected for the presence of bubbles. If bubbles are observed, the sampler will attempt to add sample volume to the vial to remove the bubbles. If bubbles continue to form, indicating effervescence, the sample will be discarded and recollected. The laboratory will be notified that the samples are unpreserved and the analyses will be completed within the appropriate holding time (i.e., 7 days).

Parameters that require filtering will be collected following the attachment of a disposable 0.45 µm in-line filter to the discharge tubing.

- iii) All equipment used during sampling which may have come in contact with potentially contaminated waters will be decontaminated. Latex gloves used during the collection of the samples will be disposed of. The pump discharge line and air supply line will either be dedicated and left hanging in the well or disposed of after the well has been sampled.
- iv) QC samples will be collected for chemical analysis as discussed in Section J 4.0. Samples will be handled as discussed in Section J 5.0.

J 2.3 SURFACE WATER

Surface water monitoring and sampling will be conducted at the Site in order to verify groundwater flow direction, aquifer response, groundwater recharge/discharge, groundwater migration, and human health and ecological risks associated with exposure to Site surface water.

J 2.3.1 STAFF GAUGE INSTALLATION

Five staff gauges will be installed at the Site. The gauges will be installed in a manner appropriate with the depth and flow velocity of the ditch, pond and /or river to

maintain the staff gauges in a stable position. Where appropriate a benchmark location on an existing structure (bridge etc.) may be used as a surface monitoring location. Figure J-2.3 presents the recommended locations of staff gauges as well as existing staff gauges. Surface water gauges will be established at all Site surface water bodies (Small Pond, Large Pond and Quarry Pond) and along the Great Miami River to the northwest of the Site. The gauges are being installed and monitored in order to fill existing hydrogeologic data gaps and understand the influence of the Great Miami River on the groundwater flow regime. In addition, the surface water monitoring gauging station located at the sewage treatment plant across the river from the Site will be monitored.

J 2.3.2 SURFACE WATER HYDRAULIC MONITORING

Hydrologic data will be collected during the implementation of the RI work plan. Manual water level measurements will be collected using an electronic depth-to-water probe accurate to +/- 0.01 feet. The measurements will be made from the survey mark or from the top of the staff gauge. The depth to surface water will be converted to elevations based on the surveyed elevation at each staff gauge location.

J 2.3.3 SURFACE WATER SAMPLING

Three surface water (Quarry Pond, Large Pond and Small Pond Site locations) and three sediment samples will be collected at the same location (surface water samples will be collected first). QC samples will be collected for chemical analysis as discussed in Section J 4.0. Surface water samples will be collected and analyzed for the parameters listed in Table J-2.3.

All equipment will be decontaminated as discussed in Section J 7.0. Decontamination water will be managed as described in Section J 8.0.

Surface water samples will be collected at each area using a precleaned stainless steel ladle attached to a pole or directly into the sample containers if possible. The sampling personnel will stay at the edge of the surface water so as not to disturb the water during sample collection. The water will be transferred from the ladle directly to sampling containers.

Field parameters will also be measured for the surface water samples. pH, temperature, and conductivity will be measured using a YSI Model 3560 instrument. DO will be measured using a YSI Model 52 instrument. Turbidity will be measured using an HF

Scientific DRT-15C Turbidimeter. Alternatively, equivalent instruments may be used. Manufacturer information is contained in Attachment A. Field calibration, preventative maintenance, and standard operating procedures are contained in Section J 6.0.

Sample volume for dissolved metals analyses will be collected into a laboratory-supplied container(s) containing no preservative. The sample will then be filtered using a peristaltic pump, new disposable tubing, and a new disposable in-line 0.45 µm filter. The filtered sample will be discharged into the appropriate sample containers for submittal to the laboratory, with preservative, as appropriate. Filtered samples will be preserved within 20 minutes of sample collection.

J 2.4 SEDIMENT

Sediment sampling will be conducted at the Site in order characterize sediments and determine the nature and extent of sediment migration, contaminate adsorption and bioconcentration. Sediment samples will be collected from the Quarry Pond, Large Pond, and Small Pond locations on-Site.

Sampling will be conducted to evaluate sediment quality. Sample locations are presented on Figure J-2.3.

Sediment samples will be analyzed for parameters as listed in Table J-2.3. QC samples will be collected for chemical analysis as discussed in Section J 2.0.

All equipment will be decontaminated as discussed in Section J 7.0. Decontamination water will be managed as discussed in Section J 8.0.

Sediment samples will be collected in accordance with the following protocols:

1. New disposable latex gloves will be used when collecting each sediment sample. Additional glove changes will be made as conditions warrant.
2. Prior to use, for each sample, all sampling equipment will be precleaned using the prescribed rinse sequence.
3. Sediment samples will be collected from downstream locations working upstream (as applicable).
4. Samples will be collected using precleaned hand tools to a maximum depth of 12 inches.

5. All samples will be homogenized in a precleaned stainless steel bowl and then transferred into the appropriate sample bottles.

Samples collected for VOC analyses will not be homogenized but placed directly into the sample containers.

Sediment samples will be collected using a precleaned stainless-steel ladle attached to a pole. The sediment will be transferred from the ladle directly to the sampling containers. Samples for VOC analyses will be collected first using the En Core™ sampler, and collecting the sample volume from the center of the stainless steel ladle. Samples for analysis of other parameters will be collected from the remaining material using glass jars. Samples for VOC analyses will be collected using the disposable En Core™ sampler as follows:

- hold coring body and push plunger rod down until small o-ring rests against tabs. This will assure that plunger moves freely;
- depress locking lever on En Core™ T-Handle. Place coring body, plunger end first, into open end of T-Handle, aligning the 2 slots on the coring body with the 2 locking pins in the T-Handle. Twist coring body clockwise to lock pins in slots. Check to ensure sampler is locked in place. Sampler is ready for use;
- turn T-Handle with T-up and coring body down. This positions the plunger bottom flush with the bottom of the coring body (ensure that the plunger bottom is in position). Using the T-Handle, push sampler into soil until coring body is completely full. When full, small o-ring will be centered in T-Handle viewing hole. Remove sampler from soil. Wipe excess soil from coring body exterior;
- cap the coring body while it is still on the T-handle. Push and twist the cap over the bottom until grooves on locking arms seat over the ridge on the coring body. CAP MUST BE SEATED TO SEAL SAMPLER;
- remove the capped sampler by depressing the locking lever on the T-Handle while twisting and pulling the sample from the T-Handle;
- lock the plunger by rotating the extended plunger rod fully counter-clockwise until the wings rest firmly against the tabs;
- attach a completed circular label (from En Core™ sampler bag) to the cap on the coring body; and
- return the full En Core™ sampler to zipper bag.

Samples will be handled as discussed in Section J 5.0. All sampling locations will be surveyed as discussed in Section J 2.8.1.

J 2.5 LANDFILL GAS/SOIL GAS

Five soil gas probes will be installed at an in the vicinity of the Site. Soil gas probe locations are presented on Figure J-2.4. Soil gas probes will be installed and soil gas samples will be collected in order to determine the landfill gas generation potential of the Site, volatilization potential from impacted groundwater, and any potential impacts to local residents.

J 2.5.1 GAS PROBE INSTALLATION

The soil gas probes will be installed using a 50-mm (2-inch) diameter Geoprobe dual-tube direct push technique to minimize formation disturbance. The five gas probes locations have been selected in order to characterize the potential for landfill gas migration from the Site boundary to off-Site receptors. The borehole for the each gas probe will be advanced to a target depth corresponding to the bottom of the soil gas probe screened interval. The soil gas probes will be completed using 13-mm (0.5-inch) diameter schedule 40 PVC continuous piping (i.e., no joints) with a screened interval length of 0.3 meters. The void space between the screened interval and formation will be filled with No. 3 silica sand (i.e., sand pack) to approximately 0.2 meter above the top of the screened interval. Hydrated bentonite benseal will be placed on top of the sand pack to just below ground surface. The sand pack and benseal will be placed as the Geoprobe was withdrawn to ensure that the formation does not collapse around the screened interval or riser. A lockable surface casing will be set in concrete at ground surface around each soil gas probe. The soil gas probe completion details are summarized in Figure J-2.7. The soil gas probe stratigraphic and instrumentation logs are presented in Appendix J-A. The soil gas probe locations are presented on Figure J-2.4.

Soil samples will be collected from the surface and subsurface during the soil gas probe installation for the analyses of soil physical properties (i.e., grain size analyses, fraction or organic carbon content, plasticity index, porosity, permeability, and Atterburg limits).

J 2.5.2 LANDFILL GAS/SOIL GAS MONITORING

As noted in Section 2.0 of the Work Plan , historical records for the Site suggest that un-burned municipal solid waste comprises a small percentage of the material

backfilled, and is likely limited to the central portion of the Site to the east and west. In addition, the age of the landfill suggests the potential for landfill gas generation is low. Thus, only low concentrations of methane, if any, are anticipated in soil gas.

In addition to Landfill Gas, the SOW requires the RI characterization to potential impacts from VOCs in the soil gas from landfilling activities or from off gassing from groundwater. However, due to the presence of commercial, industrial, and residential structures bordering the Site, landfill gas probes are proposed to be installed to evaluate landfill gas generation rates and establish whether there is any off-Site migration of landfill gas and if so, at what concentrations. Figure J 2.6 shows the location of the five proposed landfill gas probes. One probe is located along the west-central part of the Site where municipal waste may have been deposited, and the other four are located along the east and southeast Site boundary where structures are located.

The soil gas sampling will be conducted 1 week following soil gas probe installation. Following soil gas probe installation, 1 week is considered to provide more than sufficient time for any formation disturbances created by drilling activities to dissipate and for equilibrium conditions to be reestablished in the unsaturated zone. As a result, the soil gas samples are considered representative of steady-state conditions in the unsaturated zone.

The soil gas samples will be collected using 6-liter capacity Summa™ canisters fitted with a laboratory calibrated critical orifice flow regulation device sized to allow the collection of the soil gas sample over a 1-hour sample collection time. The 1-hour sample collection time for a 6-liter capacity Summa™ canister corresponds to a maximum soil gas sample collection flow rate of approximately 200 milliliters per minute (mL/min). This soil gas sample collection flow rate corresponds to the maximum flow rate recommended in the soil gas sampling protocol recently developed by the California Environmental Protection Agency (CAEPA) (CAEPA, 2003). A maximum flow rate of 200 mL/min is recommended to limit VOC stripping from soil, prevent the short-circuiting of ambient air from ground surface that would dilute the soil gas sample, and increase confidence regarding the location from which the soil gas sample is obtained. The low flow rate of 200 mL/min provides the most representative sample of in situ conditions. Prior to sample collection, soil gas probe purging will be conducted at a maximum flow rate of 200 mL/min. Two soil gas probe volumes (calculated based on casing and sand pack volume) will be purged to remove potentially stagnant air from the internal volume of the soil gas probe and ensure that soil gas representative of the formation is drawn into the soil gas probe.

During installation, CRA will collect one surface and one subsurface soil sample for chemical analyses. Following installation, CRA will collect two rounds of soil gas samples from each probe and screen the samples on-Site for methane concentration and LEL readings. These data will be used to determine if the presumptive remedy for the prevention of off-Site migration of landfill gas at concentrations above the LEL is necessary.

CRA will also collect one round of soil gas samples from the gas probes for VOC analyses using USEPA method TO-15. These data will also be used to assess potential human health and ecological risks at the landfill boundary due to VOC migration.

Quality control/quality assurance (QA/QC) measures to be implemented during the soil gas sampling event include maintaining a minimum negative pressure in the Summa™ canisters following sample collection, collection of one field duplicate sample, collection of an ambient air sample, and the analysis of a trip blank Summa™ canister. Further details regarding the soil gas probe sampling protocol and the applied QC/QA measures are presented in Appendix J-B

J 2.6 SEEP MONITORING

Seep monitoring will be conducted as part of the Phase I RI field work. Seep monitoring will be conducted in order to determine the existence of any active seeps from the Site to adjacent properties and the Great Miami River. Seep monitoring will be conducted along all embankments and slopes along the Site. Field staff will walk along the entire length of all slopes and embankments and perform a visual inspection for seepage.. Photographs of any observed seeps will be taken. The location of any seeps will be marked on a Site plan and documented in the field log book.

J 2.7 MISCELLANEOUS

J 2.7.1 SURVEYING

Horizontal locations will be surveyed relative to the Ohio State Plane Grid Coordinates. Elevations will be surveyed relative to the 1988 North American Vertical Datum. Horizontal locations will be surveyed to the nearest 0.5-foot accuracy. Elevations for all locations other than tops of risers will be surveyed to the nearest 0.1-foot accuracy. Elevations for monitoring wells will be surveyed to the nearest 0.01-foot accuracy.

Horizontal locations will be surveyed relative to the Ohio State Plane Grid Coordinates. Elevations will be surveyed relative to the 1988 North American Vertical Datum. Horizontal locations will be surveyed to the nearest 0.5-foot accuracy. Elevations for all locations other than tops of risers will be surveyed to the nearest 0.1-foot accuracy. Elevations for monitoring wells will be surveyed to the nearest 0.01-foot accuracy.

J 2.7.2 BATHYMETRY SURVEY

A bathymetry survey will be completed to define the bottom of the Quarry Pond utilizing an echosounder attached to a GPS receiver to maintain control of sub-meter positioning. The bathymetry data and survey line locations will be stored in a digital format using Bathylog software. The Echosounder and GPS will be programmed to collect respective data at 0.2 second time intervals. Survey data will be used to complete a map of the quarry pond.

J 2.7.3 GEOPHYSICAL INVESTIGATION

A surface geophysical investigation will be conducted to determine the existence of buried metal objects at the Site (see Figure J-2.7). The geophysical survey will be conducted over all areas of waste disposal except where USEPA conducted their May 1998 geophysical investigation. In addition, surface geophysical investigation will be performed in the portion of the Affordable Auto Parts facility (Junkyard) where buried waste may be present (as determined from the waste boundary delineation). The survey will be conducted in order to identify any metallic anomalies located at the Site. It is noted that the presence of automobiles and other metals at the Affordable Auto Parts facility may cause a interference with the geophysical survey.

The surface geophysical investigation will consist of collecting data on 40-foot spaced grid lines with intermediate 20-foot spaced grid lines over anomalous areas. The geophysical instruments used to collect the geophysical data will include:

- GEM GSM-19 Proton Precession Magnetometer (or equivalent such as EG&G Geometrics G-858G cesium vapor magnetometer) to collect total magnetic field and magnetic gradient data;
- Geonics, Inc. EM-31 Ground Conductivity Meter to collect quadrature (terrain conductivity) and in-phase (metal detection) data; and
- Geonics, Inc. EM-61 Buried Metal Detector to collect focused metal detection data.

Instrumentation Description

The magnetometer records total magnetic field data from two sensors, top and bottom. The difference in total magnetic field between the two sensors divided by the vertical distance between the sensors equals the magnetic gradient. The top sensor is much less affected by small surficial or near surface ferrometallic objects, compared to the bottom sensor. The strong variations in total magnetic field (top sensor) are generally due to the presence of large ferrometallic objects.

The EM-31 electromagnetic instrument consists of two small diameter electromagnetic coils mounted on a horizontal boom, approximately 13 feet apart. The induction of an electromagnetic field in one coil induces an electromagnetic field response in the subsurface. The magnitude of this response is measured in the second coil and is proportional to the terrain conductivity of the subsurface. The rate of decay of this response provides the in-phase or metal detection data. The depth of investigation of the EM-31 is approximately 20 feet and in a hemispherical form. Since the EM-31 coil spacing and thus area investigated is relative large, the EM-31 instrument is less affected by small surficial metallic objects.

The EM-61 electromagnetic instrument consists of two horizontal large diameter coils stacked vertically, on a wheeled cart or backpack. The EM-61 works on the same principles as the EM-31, however, since the coils are stacked vertically, the terrain conductivity response is negated and is not recorded. The in-phase response is generated by the presence of metallic (ferrous and non-ferrous) objects located partially or completely beneath the coils. Objects fully outside the coils do not have an electromagnetic field induced and thus do not affect the EM-61 response, in contrast to the EM-31 and magnetometer, which cover larger areas.

The geophysical survey procedures will be as follows:

1. The geophysical survey grid will be set up such that survey lines are spaced 40 feet apart. Wooden survey stakes labeled with the grid coordinates will be placed at 50-foot intervals along each gridline via surveying. Horizontal locations will be surveyed relative to the Ohio State Plane Grid Coordinates. Elevations will be surveyed relative to the 1988 North American Vertical Datum. Horizontal locations will be surveyed to the nearest 0.5-foot accuracy. Elevations for all locations other than tops of risers will be surveyed to the nearest 0.1-foot accuracy. Elevations for monitoring wells will be surveyed to the nearest 0.01-foot accuracy.

2. Geophysical data will be collected using a data logger on each geophysical instrument. The data recording for the magnetometer and EM-31 will be initiated for each station by the operator pressing the recording button. The station spacing for the magnetometer and EM-31 will be approximately 5 feet, and be determined via pacing. The EM-61, if used in wheeled mode, will automatically trigger the data logger. The EM-61, if used in backpack mode, will require the operator to press the recording button at 5-foot intervals.
3. The magnetometer survey will also include the use of a base station to determine diurnal variation. Base station(s) will be set up in area(s) free of ferromagnetic waste and base station readings will be recorded at approximate 1-hour intervals.
4. Data reduction will include downloading from the data loggers to a computer. The downloaded data will be processed for location. Magnetometer data may be corrected for diurnal variation, if required.
5. The data will be contoured using SURFER® (Golden Software, Inc.). Separate contour plots for each data type will be prepared. Manual interpretation of the plots will be performed to assess the identified anomalies. This interpretation will include identification of anomalous areas for further investigation.

J 2.8 PRIVATE/POTABLE WELL SAMPLING

Taps selected at the Valley Asphalt property for sample collection will be located as close to the two potable wells as possible and upstream of any treatment system or storage/pressure tank. The potable piping system will have to be understood prior to sampling to determine which tap(s) are to be sampled. All water treatment devices in use at the property (i.e., water softener, filtration unit) will be noted. Leaking taps that allow water to flow out from around the stem of the valve handle and down the outside of the lip will be avoided as sampling locations. Aerator, strainer and hose attachments on the tap will be removed before sampling. The cold water tap will be opened for 10 to 15 minutes to permit cleaning the service line. A smooth-flaring water stream at moderate pressure without splashing will be obtained. Then, without changing the water flow, which could dislodge some particles in the faucet, the sample will be collected. Samples will be analyzed for the parameters which are to be determined. Field QC samples will be collected as discussed in Section J 4.0. Samples will be handled as discussed in Section J 5.0.

The well configuration (i.e., depth, casings, construction date), pumping system, piping system, (i.e., pipe type, lead-joint construction), and presence of treatment devices will be documented to the extent the information is readily available.

J 2.9 POTENTIAL ADDITIONAL ACTIVITIES

The RI/FS Work Plan references additional investigative activities that may be undertaken, depending upon the results of the activities discussed herein. Any such additional investigative activities will be conducted in accordance with work plans or technical memoranda that have been approved by USEPA.

J 2.10 SITE RESTORATION/PROJECT CLOSEOUT

Final Site restoration/project closeout activities will be performed at the completion of RI work. Site restoration/project closeout activities will include, but not necessarily be limited to, decontamination of equipment and materials and removal of investigation derived waste.

J 3.0 POTENTIAL ADDITIONAL ACTIVITIES

The following presents additional activities, which may be conducted in future investigative/confirmatory sampling events at the Site. The following activities may or may not be completed as part of any future work at the Site.

J 3.1 BEDROCK WELL INSTALLATION

Should bedrock monitoring wells need to be advanced at the Site the following installation and construction techniques will be followed:

1. Polyethylene sheeting and plywood shall be laid out at each off-Site drilling location in order to contain any spills;
2. Advancement of each borehole through the overburden to bedrock, and as far into bedrock as reasonably necessary to install steel surface casing using an appropriately sized tricone bit or hollow stem augers. Since both the overburden and shallow portion of the bedrock potentially contain elevated concentrations of VOCs, the steel surface casing will likely extend to a depth of approximately 200 to 250 feet bgs. The final decision on depth to install surface casing will be made by the field representative. Bedrock is anticipated to occur at a depth of between 200 and 250 feet bgs;
3. Install steel surface casing set into the bedrock and grouted in place with cement grout, including filling the entire annular space between the steel casing and the borehole wall. The cement grout shall be allowed to cure for a period of at least 48 hours. It is intended that the steel surface casing shall act as the protective casing upon completion of the well installation, therefore the surface casing shall extend two to three feet above ground surface;
4. Test the integrity of the cement seal by filling the surface casing with potable water and routinely measuring the water level for a period of 15 minutes. The water level should not drop more than 0.3 feet, if the water level drops more than 0.3 feet during this time;
5. Advance the borehole by HQ or PQ coring, or equivalent, to a total depth of up to 50 feet below the top of competent bedrock order to determine major flow zone(s) within the bedrock;
6. Develop the well via airlift methods to a relatively sediment/cuttings free condition if conducting packer flow tests after completion of coring;

7. Conduct packer flow tests of up to 1 hour duration for each test utilizing a submersible pump installed between inflatable packers at 5-foot intervals after coring to final depth, in order to determine flow rate from each interval;
8. Backfill the lower portion of the borehole, if required with bentonite gravel to the specified depth as determined by the field representative;
9. complete the boreholes as monitoring wells with number 10 slot, 5- or 10-foot long Schedule 40 PVC well screens and flush-threaded Schedule 40 PVC riser pipe allowing for approximately 3 feet of stick-up;
10. Place a sand pack around the screen extending to 2 feet above the screen;
11. Place a 3-foot bentonite gravel seal in the borehole annulus directly above the sand pack;
12. backfill the remaining borehole annulus above the bentonite gravel seal with bentonite grout, using the positive displacement method, to ground surface within the surface casing; and
13. Install lockable caps sized to fit on the steel surface casing enclosing the riser pipe at each monitoring well location.

Drill cuttings and decontamination water will be managed as discussed in Section J 8.0.

J 4.0 FIELD QUALITY CONTROL SAMPLING

J 4.1 GENERAL

The sampling and analysis program associated with the RI are summarized in Table J-2.1, Table J-2.2, and Table J-2.3. The tables also present a summary of field QC sampling for laboratory chemical analysis and summarizes the frequency of each type of field QC sample to be collected for each investigative activity.

The following types of field QC samples will be collected for laboratory chemical analysis:

- field duplicate samples;
- equipment blank/decon water samples;
- matrix spike/matrix spike duplicate (MS/MSD) samples; and
- trip blank samples.

Each type of field QC sample for laboratory chemical analysis is discussed below.

J 4.2 FIELD DUPLICATE SAMPLES

During the RI, field duplicate samples will be collected and submitted to the laboratory. Field duplicate samples will be collected in a manner whereby as the sample fraction for each parameter is collected, the sample medium will be equally split between the investigative fraction and the duplicate fraction for that parameter. VOC fractions for aqueous samples will be filled continuously until an individual vial is completely filled before filling a vial for a duplicate sample. One field duplicate will be collected for each 10 or fewer investigative samples submitted.

J 4.3 EQUIPMENT BLANK SAMPLES

Equipment blank samples will be collected for any sampling activity that requires equipment decontamination. One equipment blank will be collected for each ten or fewer investigative samples submitted.

The equipment blank will be obtained by passing analyte-free laboratory-supplied, deionized water through a cleaned sampling apparatus (i.e., bladder pump or sampler) and collecting it in a clean container. Specifically, the equipment blank for the bladder

pump will be collected by attaching a short length of discharge tubing to the pump, turning the pump upside down and pouring laboratory-supplied deionized water through the pump and into the appropriate sample containers.

J 4.4 MATRIX SPIKE/MATRIX SPIKE DUPLICATE SAMPLES

MS/MSD sample volumes are additional sample aliquots provided to the laboratory to evaluate the accuracy and precision of the sample preparation and analysis technique.

Two times the normal sample aliquot is required for VOCs, SVOCs, pesticides, and PCBs to conduct MS/MSD analyses. No additional sample volume is required for inorganics or general chemistry parameters. Sample collection is identical to the technique described for collection of field duplicates. Sample labeling identifies the respective sample location and each additional container which is labeled as the "MS/MSD" volume.

One MS/MSD sample will be collected for each 20 or fewer investigative samples submitted.

J 4.5 TRIP BLANK SAMPLES

Trip blank samples will be used to determine if the sample shipping or storage procedures have influenced the analytical results. Trip blanks will be prepared by the laboratory using deionized water and preservative and sent to the Site in the shipping container(s) designated for the project. These samples will be kept with the investigative samples, then submitted to the laboratory for analysis with the investigative samples. The samples will not be opened.

Trip blanks will be analyzed for TCL VOCs only. One trip blank will be submitted for each cooler containing sample media for analysis of aqueous VOCs.

J 5.0 SAMPLE CUSTODY AND DOCUMENT CONTROL

CRA follows the USEPA Region 5 sample custody protocols described in "NEIC Policies and Procedures", EPA-330/9-78-001-R, revised August 1991. This custody is segregated into three parts: sample collection; laboratory analysis; and final evidence files. Final evidence files, including all originals of laboratory reports, are maintained under document control in a secure area.

A sample or evidence file is in a person's custody if:

- the item is in actual possession of a person; or
- the item is in the view of the person after being in actual possession of the person; or
- the item was in actual physical possession of the person and is secured in an appropriate container and arrangements are made to transport it to the laboratory via a bonded courier; or
- the item is in a designated and identified secure area.

J 5.1 SAMPLE LABELING

Each sample container will be labeled with a unique sample number that will facilitate tracking and cross-referencing of sample information and will be recorded in the field logbook. The unique sample number will be recorded with the sample location in the field logbook at the time of sample collection. The field logbook will form part of the permanent field record. The sample numbering system to be used is described as follows (the information entered on the sample labels will be printed by the field sampler):

Example: GW-LOC-MMDDYY-D

Where:

- | | |
|--------|--|
| GW | - designates types of sample (GW-groundwater, S-soil, SW-surface water, SD-sediment) |
| LOC | - designates sample location (i.e., MW-1, BH-1, etc.); |
| MMDDYY | - designates date of collection presented as month, day, year; and |
| D | - designates type of field QC sample (D-field duplicate, E-equipment blank). This suffix will only be used for field QC samples. |

Trip blank samples also will be numbered with a unique sample number. The sample numbering system to be used for such samples is described as follows (the information entered on the sample labels will be printed by the field sampler):

Example:

TRIP BLANK - MMDDYY-N

where:

- MMDDYY - designates date of collection presented as month, day, year; and
- N - designates sequential number of each type of the two samples, starting with 1 at the beginning of the Phase II RI activities.

An example of the sample label is provided on Figure J-5.1.

J 5.2 FIELD CHAIN-OF-CUSTODY PROCEDURES

The sample packaging and shipment procedures summarized below will insure that the samples will arrive at the laboratory with the chain-of-custody intact. The Field QA Officer will be responsible for oversight of field documentation procedures.

J 5.2.1 FIELD PROCEDURES

1. The field sampler is personally responsible for the care and custody of the samples until they are transferred to another individual or properly dispatched to the laboratory. As few people as possible should handle the samples.
2. All containers will be labeled with unique sample numbers.
3. Sample labels will be completed for each sample using waterproof ink.

J 5.2.2 FIELD LOGBOOKS/DOCUMENTATION

Field logbooks will provide the means of recording data collecting activities performed. As such, entries will be described in as much detail as possible so that persons going to the Site could reconstruct a particular situation without reliance on memory.

Field logbooks will be bound field survey books or notebooks. Logbooks will be assigned to field personnel and will be stored in CRA's Cincinnati, Ohio office when not in use. Each logbook will be identified by a project-specific number which includes the project number (38443).

The title page of each logbook will contain the following:

- person to whom or task for which the logbook is assigned;
- project number;
- project name;
- the starting date for entries into the logbook; and
- the ending date for entries into the logbook.

Entries into the logbook will contain a variety of information. At the beginning of each day's logbook entry, the date, start time, weather, names of all sampling team members present, and the signature of the person making the entry will be entered. The names of individuals visiting the Site or field sampling team and the purpose of their visit will also be recorded in the field logbook.

All field measurements taken and samples collected will be recorded. All logbook entries will be recorded in ink, signed and dated. If an incorrect logbook entry is made, the incorrect information will be crossed out with a single strike mark, which is initialed and dated by the person making the erroneous entry. The correct information will be entered into the logbook adjacent to the original entry.

Whenever a sample is collected or a measurement is made, a detailed description of the location will be recorded in the logbook. Photographs taken at a location, if any, will also be noted in the logbook. All equipment used to obtain field measurements will be recorded in the field logbook. The sample numbering system (as described in Section 5.1) will be recorded in the field logbook correlating the unique sample number to the sample location and sample depth (if necessary). In addition, the calibration data for all field measurement equipment will be recorded in the field logbook.

Samples will be collected following the sampling procedures documented in this FSP. The equipment used to collect samples, time of sample collection, sample description, and volume and number of containers will be recorded in the field logbook.

J 5.2.3 TRANSFER OF CUSTODY AND SHIPMENT PROCEDURES

The sample packaging and shipping procedures summarized below will ensure that the samples arrive at the laboratory with the chain-of-custody intact.

1. The field sampler is personally responsible for the care and custody of the samples until they are transferred to another person or the laboratory. As few people as possible will handle the samples.
2. All sample containers will be identified by using sample labels which include the date of collection, unique sample number, and analyses to be performed.
3. Sample labels will be completed for each sample using waterproof ink.
4. Samples will be placed in coolers containing ice immediately after collection.
5. Samples will be accompanied by a properly completed chain-of-custody form. An example chain-of-custody form is in Attachment J-B. The sample identification numbers will be listed on the chain-of-custody form. When transferring the possession of samples, the individuals relinquishing and receiving the samples will sign and record the date and time on the form. The chain-of-custody form documents sample custody transfers from the sampler to another person, to the laboratory, or to/from a secure storage area.
6. All sample shipments will be accompanied by the chain-of-custody form identifying its contents. The chain-of-custody form is a four-part carbonless-copy form. The form is completed by the sampling team and, after signing and relinquishing custody to the shipper, retains the bottom (goldenrod) copy. The shipper, if different than the sampling team members, retains the pink copy after relinquishing custody to the laboratory. The yellow copy is retained by the laboratory and the fully executed top copy is returned as part of the data deliverables package.
7. Samples will be properly packaged for shipment (see Table J-5.1) and dispatched to the appropriate laboratory for analysis with a separate signed chain-of-custody form enclosed in and secured to the inside top of each shipping cooler. Shipping coolers will be secured with custody tape for shipment to the laboratory. The custody tape is then covered with clear plastic tape to prevent accidental damage to the custody tape.
8. If the samples are sent by common carrier, a bill of lading will be used and copies will be retained as permanent documentation. Commercial carriers are not required to sign the chain-of-custody form as long as the form is sealed inside the sample cooler and the custody tape remains intact.

9. If samples are not shipped to the laboratory the same day the samples are collected in the field, additional ice will be placed in the coolers, the coolers will be sealed and kept in a designated secure area until they are shipped to the laboratory as described above.

J 5.3 LABORATORY CHAIN-OF-CUSTODY PROCEDURES

Laboratory sample custody begins when the samples are received at the laboratory. The laboratory's sample custodian will assign a unique laboratory sample identification number to each incoming sample. The field sample identification numbers, laboratory sample identification numbers, date and time of sample collection, date and time of sample receipt, and requested analyses will be entered into the sample receiving log. The laboratory's sample log-in, custody, and document control procedures are detailed in the appropriate SOPs in the QAPP (Appendix K of the RI/FS WP).

J 5.4 LABORATORY STORAGE OF SAMPLES

Following log-in, all samples will be stored within an access-controlled location and will be maintained properly preserved (as defined in Table J-5.1) until completion of all laboratory analyses. Unused sample aliquots and sample extracts/digestates/distillates will be maintained properly preserved for a minimum of 30 days following receipt of the final report by CRA. The laboratory will be responsible for the disposal of unused sample aliquots, samples, containers, and sample extracts/digestates/distillates in accordance with all applicable local, state, and federal regulations.

The laboratory will be responsible for maintaining analytical log books and laboratory data. Raw laboratory data files will be inventoried and maintained by the laboratory for a minimum period of 7 years, after which time CRA will advise the laboratory regarding additional storage.

J 5.5 FINAL EVIDENCE FILES CUSTODY PROCEDURES

Evidential files for the entire project will be maintained by CRA and will consist of the following:

- i) project plan;
- ii) project log books;

- iii) field data records;
- iv) sample identification documents;
- v) chain-of-custody records;
- vi) correspondence;
- vii) references, literature;
- viii) final laboratory reports;
- ix) miscellaneous - photos, maps, drawings, etc.; and
- x) final report.

The final evidence file materials will be the responsibility of the evidentiary file custodian (CRA's Project Manager) with respect to maintenance and document removal. Section XIV of the ASAOC specifies that all records be maintained for a minimum of 10 years after commencement of construction of any remedial action. USEPA is to be notified at least 90 days before the documents are scheduled to be destroyed. All records for the RI/FS will be maintained consistent with the requirements of the ASAOC.

J 6.0 FIELD CALIBRATION, PREVENTATIVE MAINTENANCE, AND STANDARD OPERATING PROCEDURES

J 6.1 PHOTOIONIZATION DETECTOR (PID)

The PID(s) will be maintained and used according to the manufacturer's specifications. The operating manual is kept in the instrument case. Field calibration, including date, time, standard used, results, and corrective actions taken will be recorded in the field logbook. The PID will be calibrated at least once daily, prior to use. Recalibration will be undertaken at more frequent intervals if there is any indication of faulty performance. Calibration check results must be ± 10 percent of the true value. If the result is outside of ± 10 percent, the meter will be recalibrated. Field calibration will be carried out according to the manufacturer's procedure. All initial and continuing PID calibrations performed in the field will be carried out using two reference standards.

The SOP for conducting headspace readings using the PID is in Attachment J-B. Table J-6.1 summarizes calibration check frequency and control limits.

J 6.2 pH, TEMPERATURE, ORP, AND CONDUCTIVITY INSTRUMENT

pH, temperature, conductivity, and ORP will be measured using a YSI Model 3560 instrument, or equivalent. The instrument will be calibrated daily, or as necessary, if malfunction is suspected. Initial calibration will be performed in accordance with manufacturer's requirements. The standard operating procedures are in Attachment J-B. Table J-6.1 summarizes calibration check frequency and control limits.

J 6.3 TURBIDITY INSTRUMENT

Turbidity will be measured using an HF Scientific DRT-15C Turbidimeter, or equivalent. The instrument will be calibrated daily, or as necessary, if malfunction is suspected. Initial calibration will be performed in accordance with manufacturer's requirements. The standard operating procedures are in Attachment J-B. Table J-6.1 summarizes calibration check frequency and control limits.

J 6.4 DISSOLVED OXYGEN INSTRUMENT

Dissolved oxygen will be measured using a YSI Model 52 instrument, or equivalent. The instrument will be calibrated daily, or as necessary, if malfunction is suspected. Calibration will be performed in accordance with manufacturer's requirements. The standard operating procedures are in Attachment J-B. Table J-6.1 summarizes calibration check frequency and control limits.

J 6.5 WATER LEVEL INDICATOR

Water level measurements will be collected using a Solinst Model 101 water level indicator, or equivalent. The instruments do not require field calibration. The only field maintenance required is battery replacement.

Water level meters are calibrated against a primary standard (steel tape or chain) once every year. The calibration records for all water level meters will be maintained in a field file and be available for review upon request.

J 6.6 LANFILL GAS METER

Landfill gas measurements will be collected using a Landtec Gas Extraction Monitor, GEM-500 meter indicator, or equivalent. The instrument will be calibrated daily, or as necessary, if malfunction is suspected. Calibration will be performed in accordance with manufacturer's requirements. The standard operating procedures are in Attachment J-B. Table J-6.1 summarizes calibration check frequency and control limits.

J 7.0 EQUIPMENT CLEANING PROTOCOLS

J 7.1 SAMPLING EQUIPMENT DECONTAMINATION PROCEDURES

Stainless steel split-spoon soil samplers and VAS samplers used for the collection of samples for chemical analysis, and stainless steel ladles used for the collection of sediment samples for chemical analysis will be cleaned prior to use and between each sampling point in accordance with the following procedure:

- brush with soapy (phosphate-free soap) water; and
- rinse with distilled water.

The water level indicator, water level plover, surge block, slug, and dissolved oxygen electrode and cable will be cleaned prior to use and between each sampling point by the following procedure:

- sprays of potable or distilled water on the outside surfaces; and
- wipe outside surface with paper towel.

The submersible pump used for well development and electric low-flow submersible pump, if used for groundwater purging and sampling, will be decontaminated prior to use and between each location according to the following procedures:

- spray the discharge tubing, reel, and pump with potable water to rinse off particulates;
- pump soapy (phosphate-free soap) water solution through the pump and tubing for a minimum of 2 minutes;
- circulate potable water through the pump and discharge tubing until all traces of soap are gone; and
- pump distilled water through the pump and tubing for a minimum of 5 minutes.

Following the collection of each groundwater sample the bladder pump will be decontaminated in the following manner:

- Pre-Rinse - Place pump in a basin (e.g., barrel or new garbage can) with potable water. Operate the pump for 5 minutes. Flush other equipment with potable water for 5 minutes.

- Wash - Operate the pump in the basin with potable water and Alconox for 5 minutes.
- Rinse - Operate pump in the basin with potable water for 5 minutes.
- Final Rinse - Operate pump in the basin with distilled or de-ionized water and pump out 1 to 2 gallons.
- The bladder pump will be wrapped in inert material (i.e., polyethylene sheeting or aluminum foil) for storage or transport.

The tubing will be dedicated to each well and either left hanging within the well for reuse or disposed of after sampling of each well is completed.

J 7.2 DRILLING EQUIPMENT

The drill rig, augers, split-spoon samplers, roto-sonic core barrels and casings, and drill rods will be steam-cleaned before startup of field operations and after each boring using a high-pressure, high-temperature, hot water cleaner. The potable water used will come from an off-Site source free of contamination (a fire hydrant may be used). One sample of potable water will be analyzed for VOCs to verify water quality. In the event that the potable water source is changed, a sample will be collected from the new source.

Split-spoon samplers will be washed before each sample is collected using a brush and non-phosphate laboratory-grade detergent, such as Alconox[®], rinsed with potable water, and rinsed again with distilled water.

J 8.0 MANAGEMENT OF INVESTIGATION-DERIVED WASTE (IDW)

The IDW materials that are expected to be produced during the RI activities include drill cuttings, development and purge water from monitoring wells, purge water from leachate wells, decontamination water, used personal protective equipment (PPE), and used disposable sampling equipment. Each of these waste streams will be managed as discussed below.

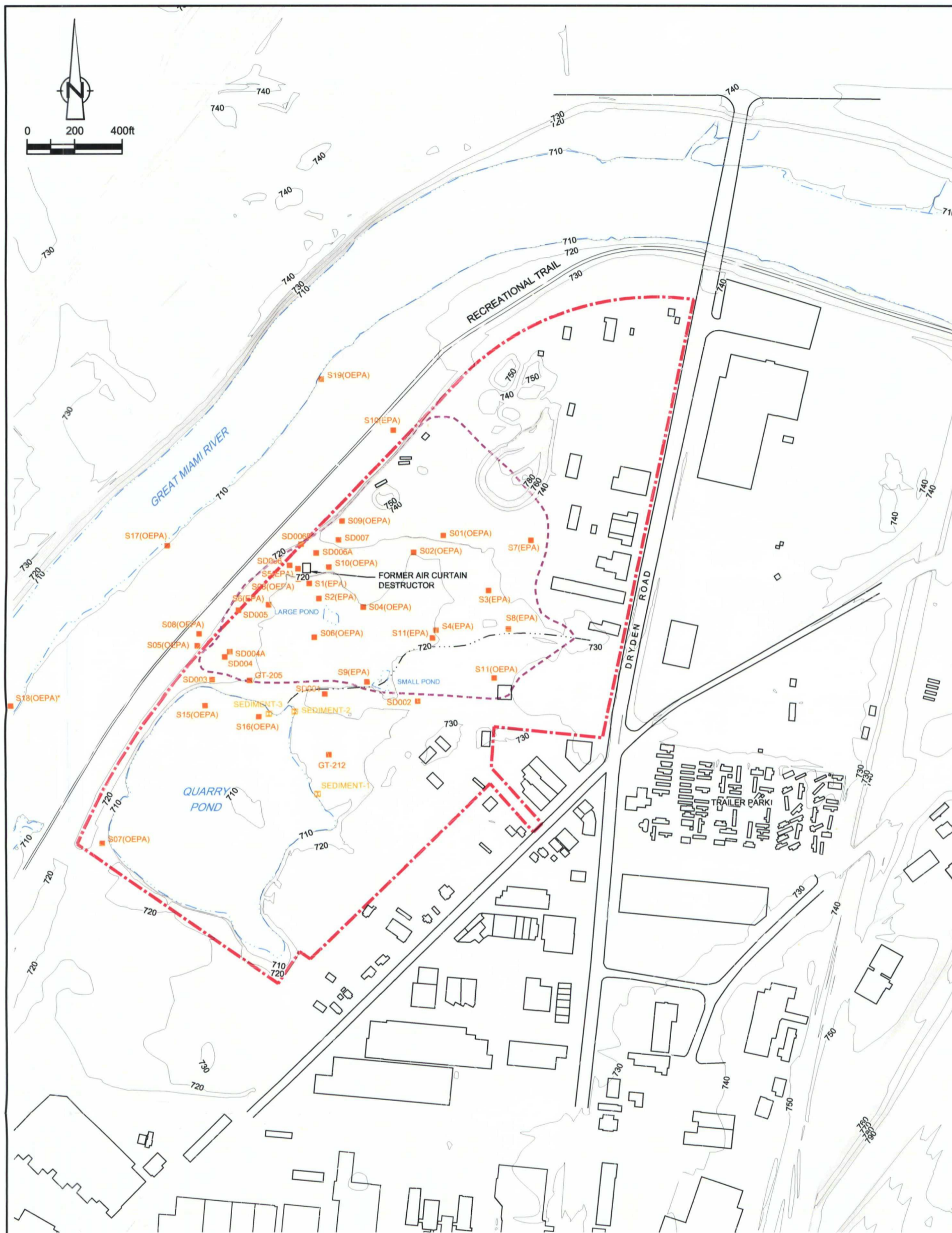
Drill cuttings will be placed in open labelled drums and which will be located adjacent to the boring locations where they were generated. Development and purge water from monitoring wells and decontamination water will be contained in sealed drum adjacent to the monitoring well location where the water was generated.

Used PPE and used disposable sampling equipment will be placed in garbage bags and stored within a designated area of the Site. At the completion of field activities, the material will be disposed of at a sanitary landfill.

J 9.0 REFERENCES

- Bouwer, H. and Rice, R.C., 1976 Revised 1986. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells. Water Resources Research 12:423-28.
- Cooper, H.H., Bredehoeft, J.D., and Papadopoulos, I.S., 1967, Response of a Finite-Diameter Well to an Instantaneous Change of Water, Water Resources Research, Vol. 3, No. 1, pp. 263-269.
- Hvorslev, M.J., 1951. Time Lag and Soil Permeability in Groundwater Observations. U.S. Army Corps of Engineers Waterways Exp. Sta. Bulletin 36, Vicksburg, Miss.
- Ohio Environmental Protection Agency, February 1995. Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring.
- United States Environmental Protection Agency, August 1991. NEIC Policies and Procedures, EPA-330/9-78-0001-R.

FIGURES



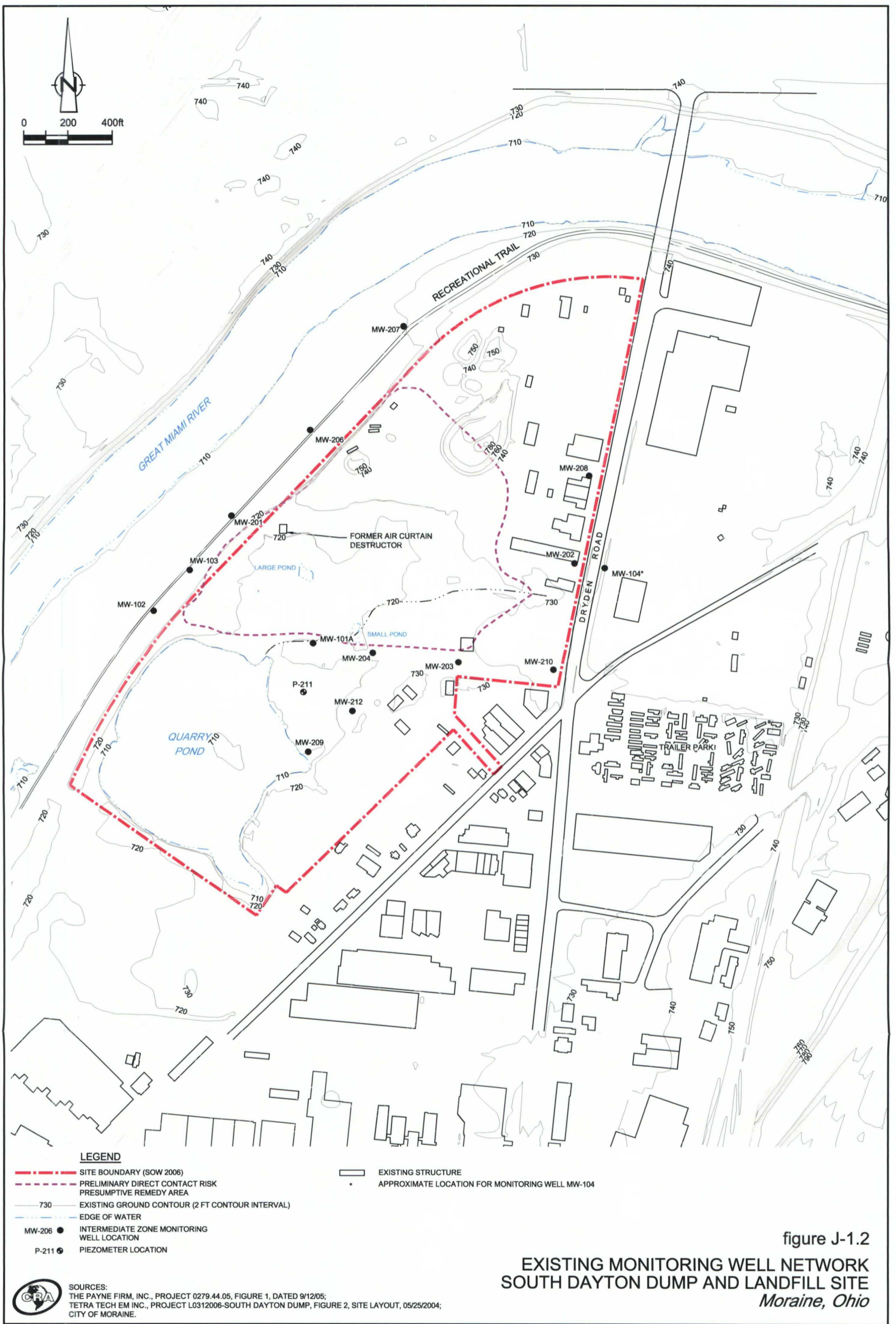
LEGEND

- SITE BOUNDARY (SOW 2006)
- PRELIMINARY DIRECT CONTACT RISK PRESUMPTIVE REMEDY AREA
- 730 EXISTING GROUND CONTOUR (2 FT CONTOUR INTERVAL)
- S01 SOIL BORING LOCATION
- SEDIMENT-1 SEDIMENT SAMPLING LOCATION
- EDGE OF WATER

figure J-1.1

**HISTORICAL SOIL SAMPLING AND BOREHOLE LOCATIONS
SOUTH DAYTON DUMP AND LANDFILL SITE
Moraine, Ohio**

SOURCES:
THE PAYNE FIRM, INC., PROJECT 0279.44.05, FIGURE 1, DATED 9/12/05;
TETRA TECH EM INC., PROJECT L0312006-SOUTH DAYTON DUMP, FIGURE 2, SITE LAYOUT, 05/25/2004;
CITY OF MORaine.



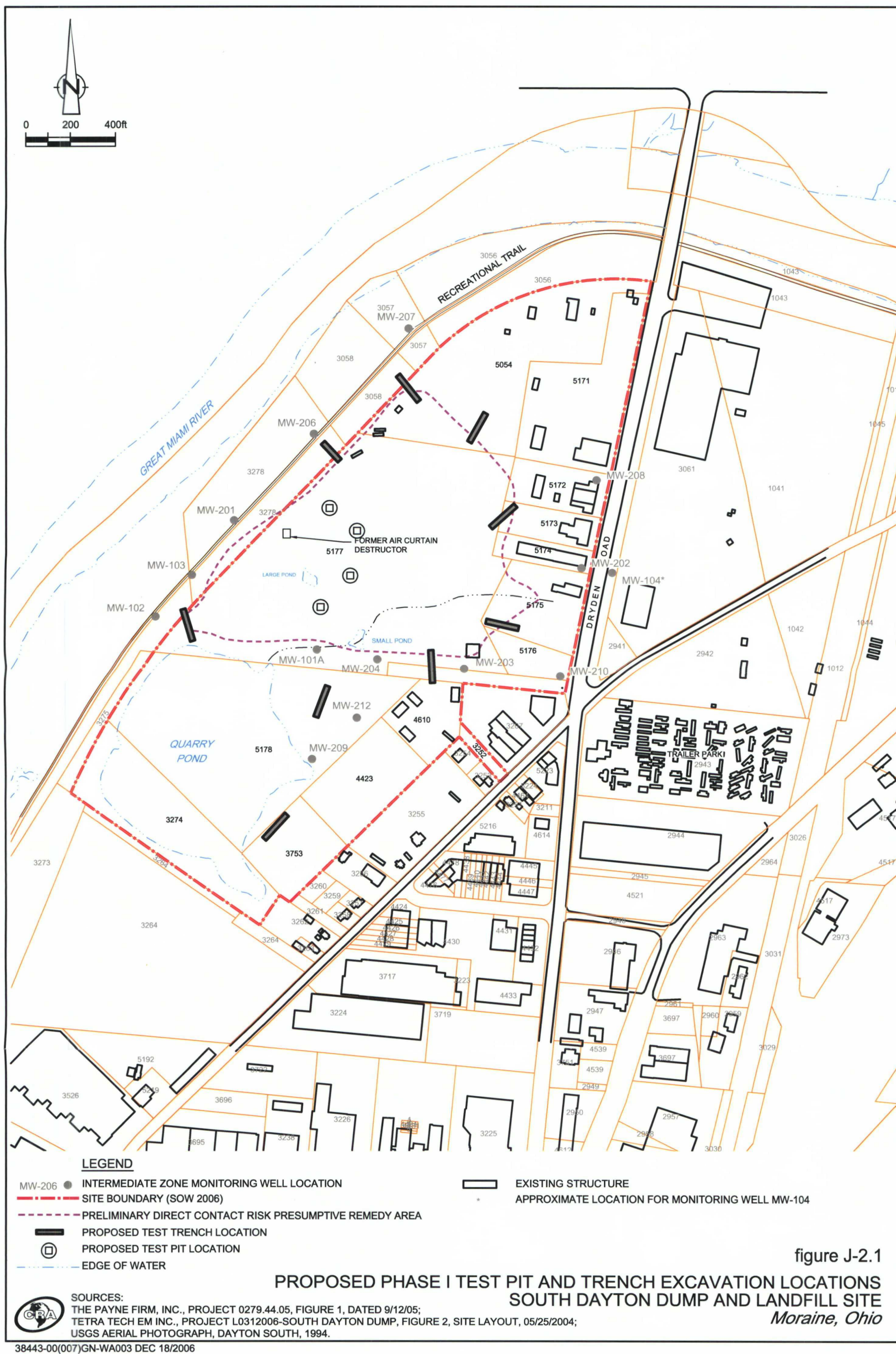


figure J-2.1

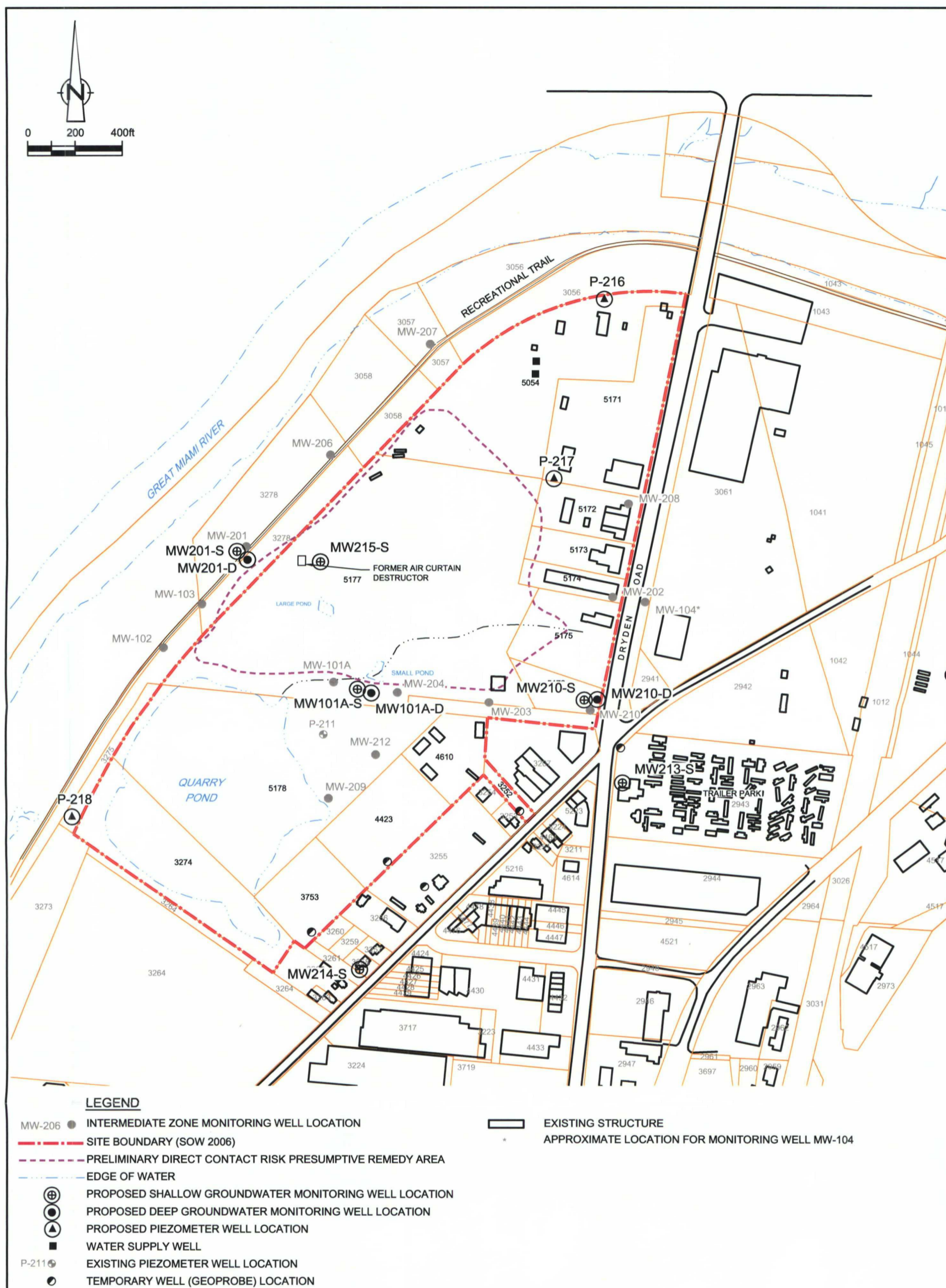
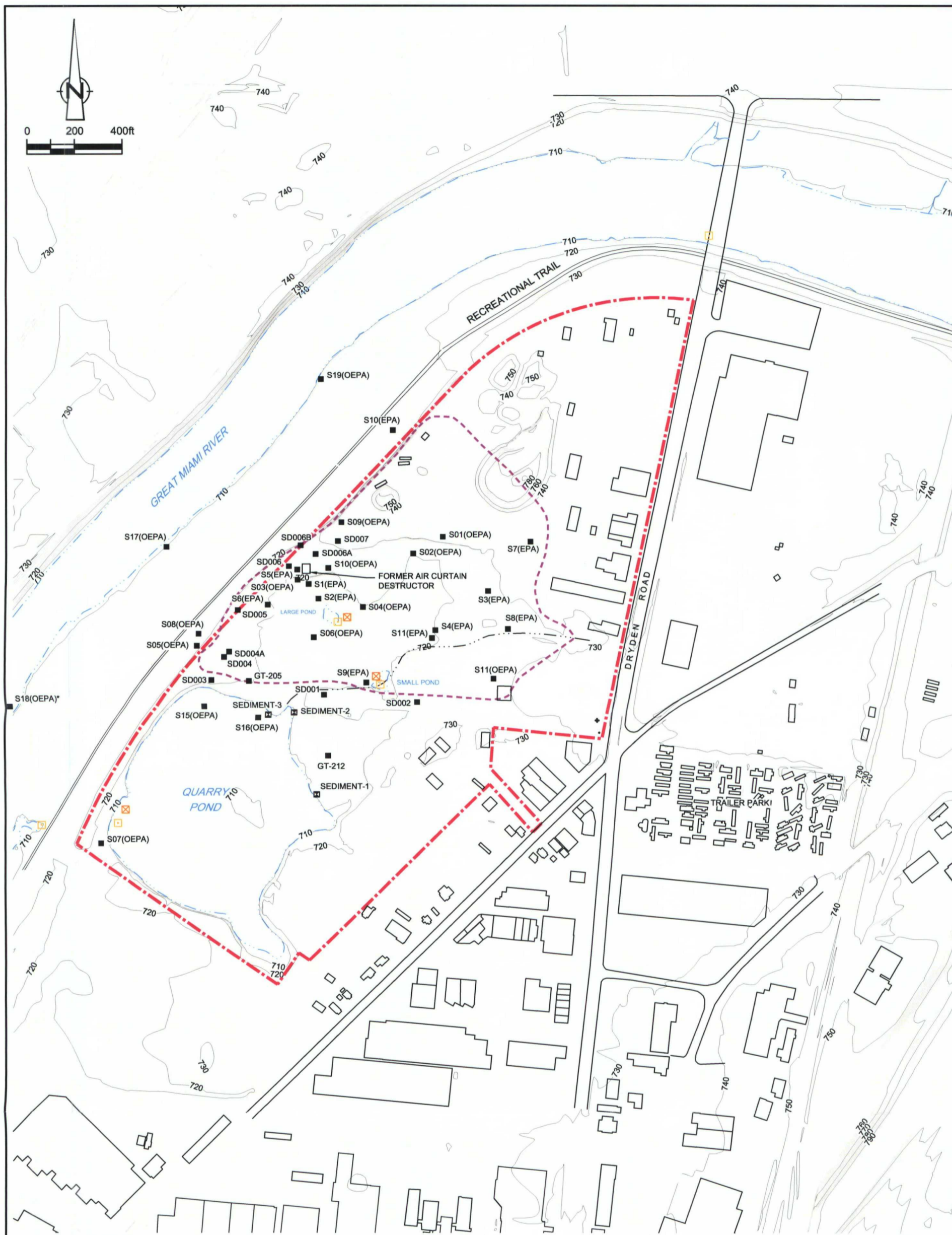


figure J-2.2

PROPOSED MONITORING/PIEZOMETER WELL LOCATIONS
SOUTH DAYTON DUMP AND LANDFILL SITE
D 9/12/05;
UMP, FIGURE 2, SITE LAYOUT, 05/25/2004;
Moraine, Ohio

SOURCES:

SOURCES:
THE PAYNE FIRM, INC., PROJECT 0279.44.05, FIGURE 1, DATED 9/12/05;
TETRA TECH EM INC., PROJECT L0312006-SOUTH DAYTON DUMP, FIGURE 2, SITE LAYOUT, 05/25/2004;
USGS AERIAL PHOTOGRAPH, DAYTON SOUTH, 1994.



LEGEND

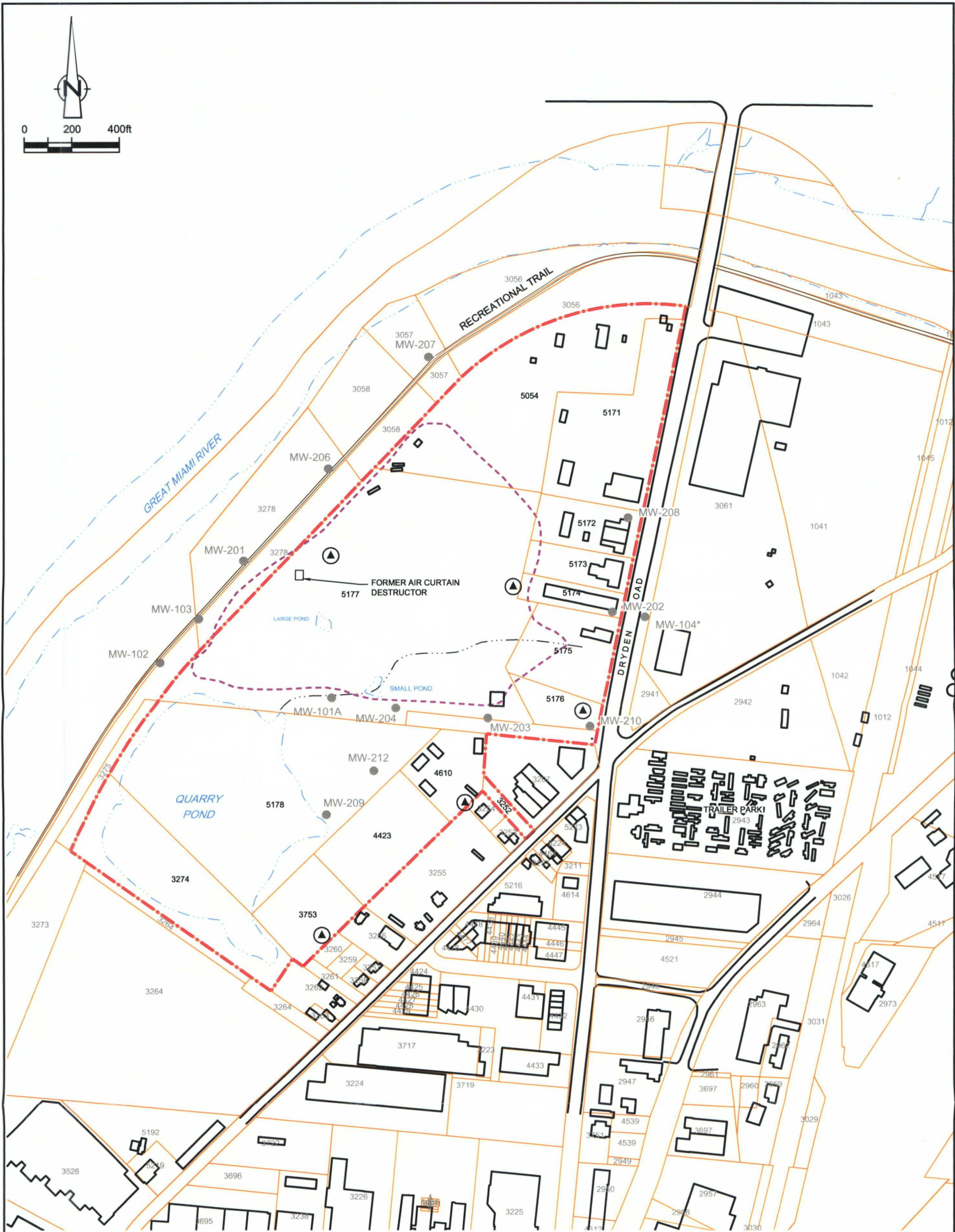
- SITE BOUNDARY (SOW 2006)
- PRELIMINARY DIRECT CONTACT RISK PRESUMPTIVE REMEDY AREA
- 730 --- EXISTING GROUND CONTOUR (2 FT CONTOUR INTERVAL)
- S01 ■ HISTORIC SOIL BORING LOCATION
- SEDIMENT-1 ■ HISTORIC SEDIMENT SAMPLING LOCATION
- EDGE OF WATER
- SURFACE WATER GAUGING STATION
- SEDIMENT SAMPLING LOCATION



SOURCES:
 THE PAYNE FIRM, INC., PROJECT 0279.44.05, FIGURE 1, DATED 9/12/05;
 TETRA TECH EM INC., PROJECT L0312006-SOUTH DAYTON DUMP, FIGURE 2, SITE LAYOUT, 05/25/2004;
 CITY OF MORaine.

**PROPOSED PHASE I SURFACE WATER AND SEDIMENT SAMPLING
 SOUTH DAYTON DUMP AND LANDFILL SITE**

figure J-2.3
 Moraine, Ohio



LEGEND

- MW-206 ● INTERMEDIATE ZONE MONITORING WELL LOCATION
- SITE BOUNDARY (SOW 2006)
- PRELIMINARY DIRECT CONTACT RISK PRESUMPTIVE REMEDY AREA
- EDGE OF WATER
- ▲ PROPOSED LANDFILL GAS PROBE LOCATION

- EXISTING STRUCTURE
- * APPROXIMATE LOCATION FOR MONITORING WELL MW-104



SOURCES:
 THE PAYNE FIRM, INC., PROJECT 0279.44.05, FIGURE 1, DATED 9/12/05;
 TETRA TECH EM INC., PROJECT L0312006-SOUTH DAYTON DUMP, FIGURE 2, SITE LAYOUT, 05/25/2004;
 USGS AERIAL PHOTOGRAPH, DAYTON SOUTH, 1994.

figure J-2.4
PROPOSED PHASE I SOIL GAS PROBE LOCATIONS
SOUTH DAYTON DUMP AND LANDFILL SITE
Moraine, Ohio

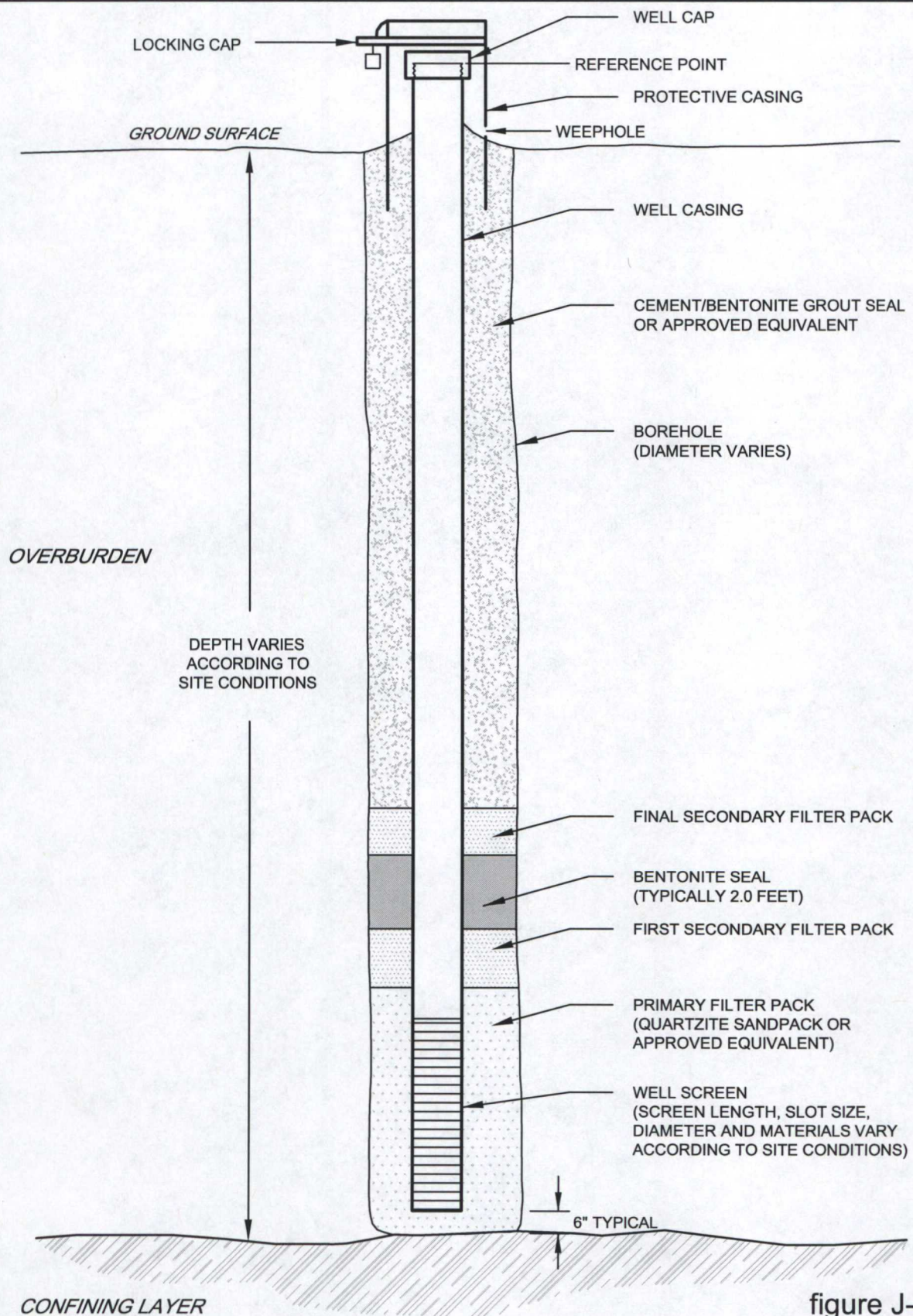
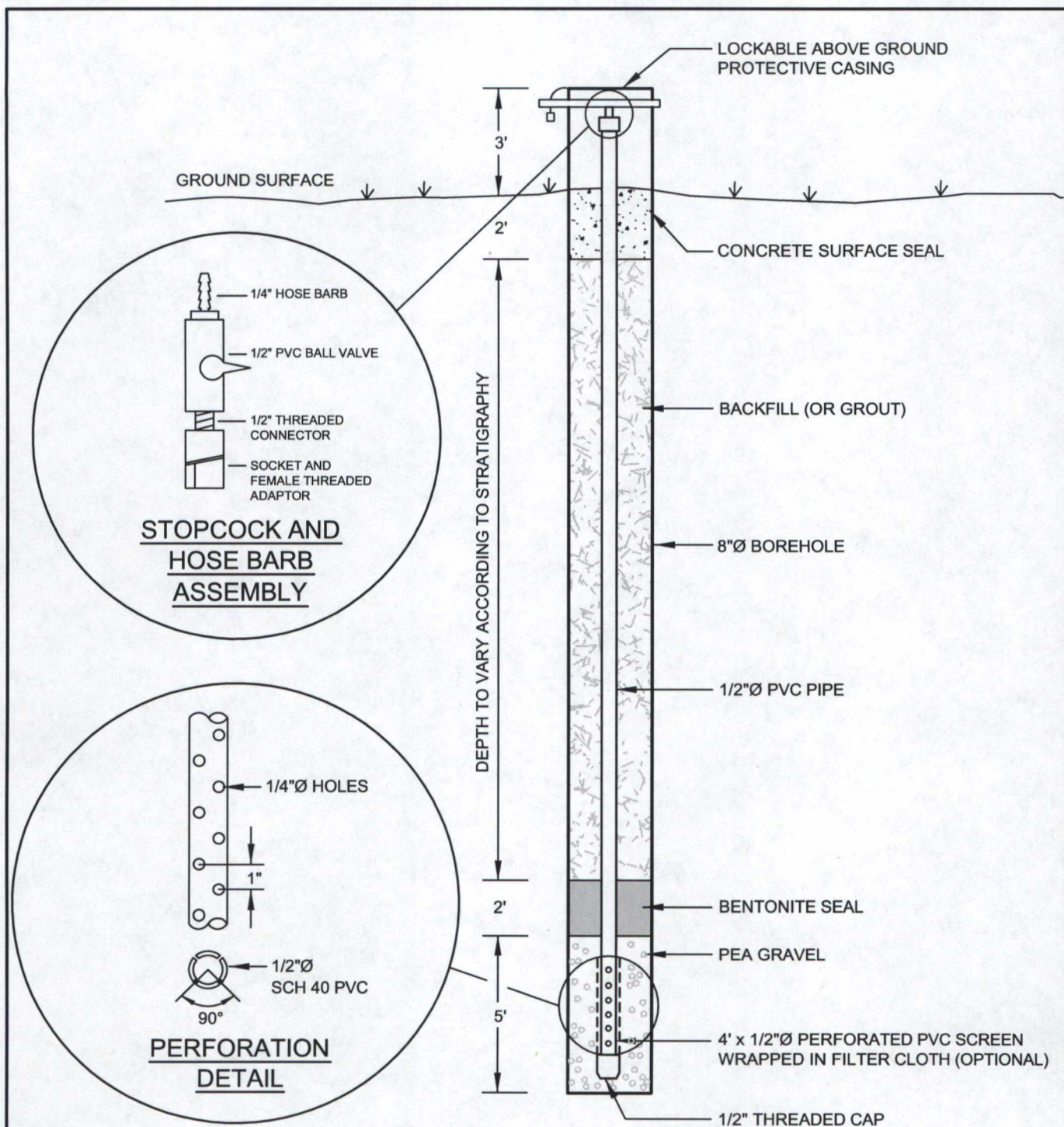


figure J-2.5

TYPICAL OVERBURDEN WELL INSTALLATION
SOUTH DAYTON DUMP AND LANDFILL SITE
Moranie, Ohio





NOTE: GAS PROBE DEPTHS AND SCREEN LOCATIONS
TO BE VERIFIED IN THE FIELD, BASED
ON LOCAL SOIL CONDITIONS
CONNECTIONS AND ADAPTORS ARE
NOT TO BE GLUED

figure J-2.6

TYPICAL MULTILEVEL GAS PROBE DETAIL
SOUTH DAYTON DUMP AND LANDFILL SITE
Moraine, Ohio



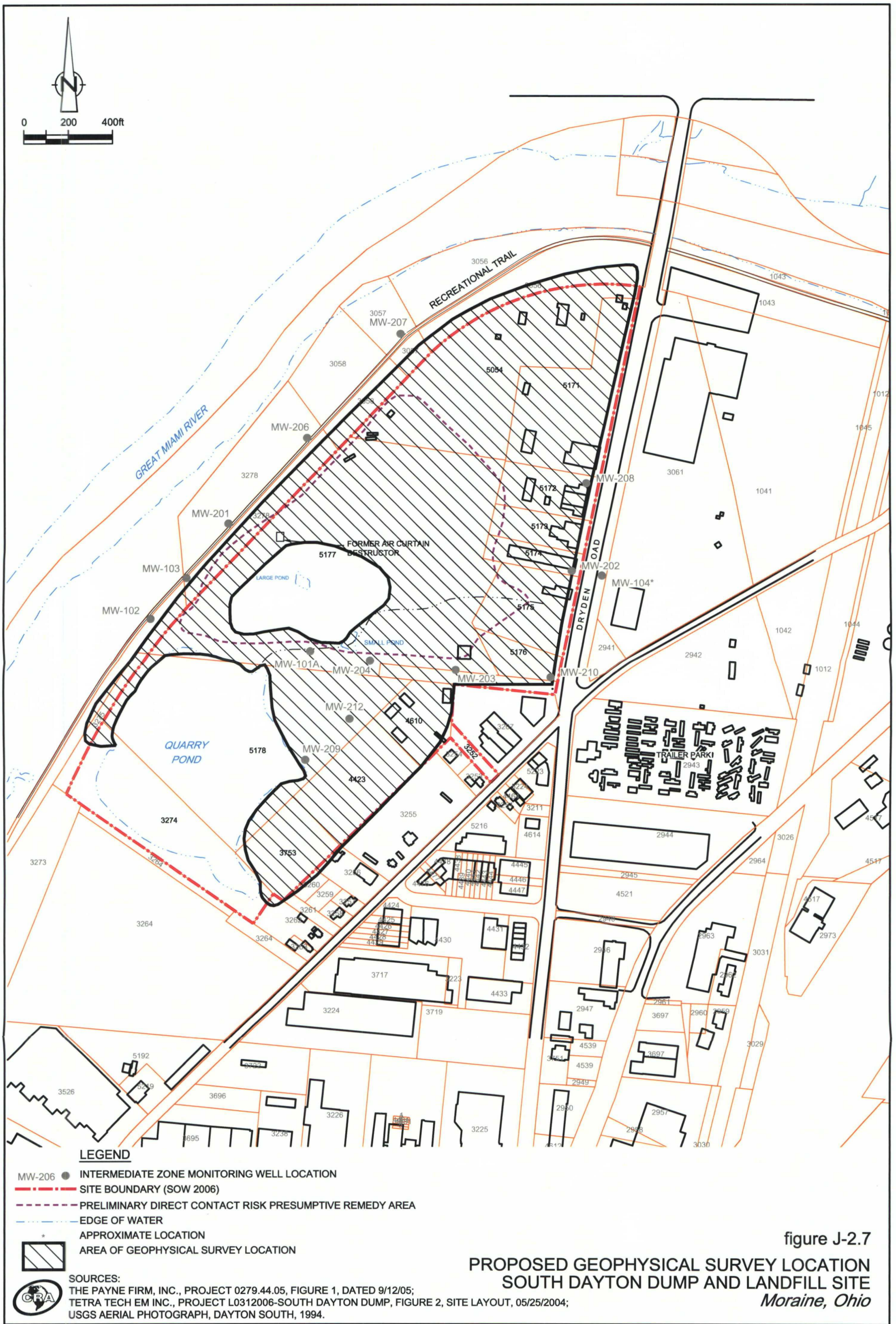


figure J-2.7
PROPOSED GEOPHYSICAL SURVEY LOCATION
SOUTH DAYTON DUMP AND LANDFILL SITE
Moraine, Ohio

CONESTOGA-ROVERS & ASSOCIATES

JOB NAME: _____

JOB NO: _____

PRESERVED? YES ☐ (Circle) NO ☐

HNO₃ HCl NaOH H₂SO₄ NaOH/ZnOAc Other

MONTH/DAY/YEAR: _____ TIME: _____

SAMPLE ID: _____

SAMPLER'S SIGNATURE: _____

LAB SAMPLE ID: _____

figure J-5.1

SAMPLE LABEL
SOUTH DAYTON DUMP AND LANDFILL SITE
Moraine, Ohio



TABLE J-2.1

**SUMMARY OF SOIL SAMPLING AND ANALYSIS PROGRAM
REMEDIAL INVESTIGATION/FEASIBILITY STUDY
SOUTH DAYTON DUMP AND LANDFILL
MORaine, OHIO**

Task/Event	Sample Matrix	Field Parameters	Laboratory Parameters	Sample Locations	Investigative Samples	Quality Control Samples ¹			Total ⁴
						Field Blanks ²	Field Duplicates	MS/MSD LCS/LCD ³	
Phase I - Surficial and Subsurface Soil Sampling									
Test Trenches - One Samples Per Distinct Fill/Waste Type	Soil	PID Screen	TCLP VOC, TCLP SVOC, TCLP Metals	TBD	TBD	—	—	--	TBD
Test Pits - One Samples Per Distinct Fill/Waste Type	Soil	PID Screen	TCLP VOC, TCLP SVOC, TCLP Metals	TBD	TBD	—	—	--	TBD
Soil Borings - Two Samples Each	Soil	PID Screen	TCL VOC, TCL SVOC, TAL Inorganics ⁵ , PCB	25	50	3	5	3	58
Soil Gas Sampling (Two Rounds)									
- Round 1	Air	PID Screen, LEL Screen	Methane, TCL VOC	5	5	—	1	1	6
- Round 2	Air	PID Screen, LEL Screen	Methane	5	5	—	1	1	6
Waste Characterization	Soil/Water	PID Screen	TCL VOC, TCL SVOC, TAL Inorganics ⁵ , PCB, MNA ⁴ TCLP Herbicides, TCLP Metals, Corrosivity, Ignitibility, Reactive Cyanide, Reactive Sulfide	TBD	TBD	--	—	--	TBD

Notes:

- ¹ - Quality control samples will include laboratory supplied trip blank amples for volatile sample analysis with each shipping cooler of aqueous investigative samples.
The actual quantity of field quality control samples will depend on field activities while maintaining the frequency specified in Section J 4.
- ² - Field blank samples consisting of equipment rinsate blanks will not be collected when dedicated or disposable sampling equipment is employed.
- ³ - Matrix spike/matrix spike duplicate (MS/MSD) or laboratory control sample/laboratory control duplicate (LCS/LCD) in the case of air samples are required for each batch of 20 samples submitted.
- ⁴ - The total quantity does not include MS/MSD or LCS/LCD samples and is dependent on the actual quantity of field quality control samples collected.
- ⁵ - TAL Inorganics include 23 metals and total cyanide.
- ⁶ - MNA - Monitored Natural Attenuation Parameters include alkalinity, chloride, dissolved organic carbon, hardness, nitrate, nitrite, sulfate, sulfite, select metals (Ca, Mg, Mn), and dissolved gases.

TCL - Target Compound List
VOC - Volatile Organic Compounds
SVOC - Semi-volatile Organic Compounds

TAL - Target Analyte List
PCB - Polychlorinated Biphenyls
TCLP - Toxic Characteristics Leachate Procedure

MNA - Monitored Natural Attenuation Parameters
DO - Dissolve Oxygen
ORP - Oxygen Reduction Potential

TABLE J-2.2

**SUMMARY OF GROUNDWATER SAMPLING AND ANALYSIS PROGRAM
REMEDIAL INVESTIGATION/FEASIBILITY STUDY
SOUTH DAYTON DUMP AND LANDFILL
MORaine, OHIO**

Task/Event	Sample Matrix	Field Parameters	Laboratory Parameters	Sample Locations	Investigative Samples	Quality Control Samples ¹			Total ⁴
						Field Blanks ²	Field Duplicates	MS/MSD LCS/LCD ³	
Phase I - Subsurface Groundwater Sampling - Two Rounds of Sampling for all Monitoring Wells									
Vertical Aquifer Sampling (VAS) (5 foot intervals - 6 depths)	Water	pH,/Temperature, Conductivity, DO, Turbidity, ORP	TCL VOC	5	30	3	3	2	36
Shallow Groundwater Investigation (Geoprobe)	Water	pH,/Temperature, Conductivity, DO, Turbidity, ORP	TCL VOC	6	6	1	1	1	7
Shallow Groundwater Investigation (New Monitoring Wells)	Water	pH,/Temperature, Conductivity, DO, Turbidity, ORP, Iron (II)	TCL VOC, TCL SVOC, TAL Inorganics ⁵ , PCB, MNA ⁶	5	10	2	2	2	14
Shallow Source Area Groundwater (New Monitoring Well - Leachate)	Water	pH,/Temperature, Conductivity, DO, Turbidity, ORP, Iron (II)	TCL VOC, TCL SVOC, TAL Inorganics ⁵ , PCB, MNA ⁶	1	2	2	2	2	6
Deep Groundwater Investigation (New Monitoring Wells)	Water	pH,/Temperature, Conductivity, DO, Turbidity, ORP, Iron (II)	TCL VOC, TCL SVOC, TAL Inorganics ⁵ , PCB, MNA ⁶	3	6	2	2	2	10
Existing Monitoring Wells	Water	pH,/Temperature, Conductivity, DO, Turbidity, ORP, Iron (II)	TCL VOC, TCL SVOC, TAL Inorganics ⁵ , PCB, MNA ⁶	13	26	2	2	2	30
Potable Well	Water	NA	TCL VOC, TCL SVOC, TAL Inorganics ⁵ , PCB, MNA ⁶	2	4	—	2	2	6

Notes:

- ¹ - Quality control samples will include laboratory supplied trip blank amples for volatile sample analysis with each shipping cooler of aqueous investigative samples. The actual quantity of field quality control samples will depend on field activities while maintaining the frequency specified in Section J 4.
- ² - Field blank samples consisting of equipment rinsate blanks will not be collected when dedicated or disposable sampling equipment is employed.
- ³ - Matrix spike/matrix spike duplicate (MS/MSD) or laboratory control sample/laboratory control duplicate (LCS/LCD) in the case of air samples are required for each batch of 20 samples submitted.
- ⁴ - The total quantity does not include MS/MSD or LCS/LCD samples and is dependent on the actual quantity of field quality control samples collected.
- ⁵ - TAL Inorganics include 23 metals and total cyanide.
- ⁶ - MNA - Monitored Natural Attenuation Parameters include alkalinity, chloride, dissolved organic carbon, hardness, nitrate, nitrite, sulfate, sulfite, select metals (Ca, Mg, Mn), and dissolved gases.

TCL - Target Compound List
VOC - Volatile Organic Compounds
SVOC - Semi-volatile Organic Compounds

TAL - Target Analyte List
PCB - Polychlorinated Biphenyls
TCLP - Toxic Characteristics Leachate Procedure

MNA - Monitored Natural Attenuation Parameters
DO - Dissolve Oxygen
ORP - Oxygen Reduction Potential

TABLE J-2.3

**SUMMARY OF SURFACE WATER AND SEDIMENT SAMPLING AND ANALYSIS PROGRAM
REMEDIAL INVESTIGATION/FEASIBILITY STUDY
SOUTH DAYTON DUMP AND LANDFILL
MORaine, OHIO**

Task/Event	Sample Matrix	Field Parameters	Laboratory Parameters	Sample Locations	Investigative Samples	Quality Control Samples ¹			Total ⁴
						Field Blanks ²	Field Duplicates	MS/MSD LCS/LCD ³	
Phase I - Surface Water Sampling									
Surface Water Guage Station	Water	pH./Temperature, Conductivity, DO, Turbidity, ORP, Iron (II)	TCL VOC, TCL SVOC, TAL Inorganics ⁵ , PCB	3	3	1	1	1	6
Phase I - Sediment Sampling									
Surface Water Guage Station	Soil	PID Screen	TCL VOC, TCL SVOC, TAL Inorganics ⁵ , PCB	3	3	1	1	1	6

Notes:

- ¹ - Quality control samples will include laboratory supplied trip blank amples for volatile sample analysis with each shipping cooler of aqueous investigative samples.
The actual quantity of field quality control samples will depend on field activities while maintaining the frequency specified in Section J 4.
- ² - Field blank samples consisting of equipment rinsate blanks will not be collected when dedicated or disposable sampling equipment is employed.
- ³ - Matrix spike/matrix spike duplicate (MS/MSD) or laboratory control sample/laboratory control duplicate (LCS/LCD) in the case of air samples are required for each batch of 20 samples submitted.
- ⁴ - The total quantity does not include MS/MSD or LCS/LCD samples and is dependent on the actual quantity of field quality control samples collected.
- ⁵ - TAL Inorganics include 23 metals and total cyanide.

TCL - Target Compound List
VOC - Volatile Organic Compounds
SVOC - Semi-volatile Organic Compounds

TAL - Target Analyte List
TCL VOC, TCL SVOC, TAL Inorganics⁵, PCB, MNA⁴
TCLP - Toxic Characteristics Leachate Procedure

MNA - Monitored Natural Attenuation Parameters
DO - Dissolve Oxygen
ORP - Oxygen Reduction Potential

TABLE J-5.1

**CONTAINER, PRESERVATION, SHIPPING AND PACKAGING REQUIREMENTS
REMEDIAL INVESTIGATION/FEASIBILITY STUDY
SOUTH DAYTON DUMP AND LANDFILL
MORaine, OHIO**

<i>Matrix</i>	<i>Analyses</i>	<i>Sample Containers</i> ¹	<i>Preservation</i> ²	<i>Maximum Holding Time from Sample Collection</i> ³	<i>Volume of Sample</i>	<i>Shipping</i>	<i>Normal Packaging</i>
<i>Groundwater, Residential Well Water</i>							
	TCL VOC, Dissolved Gases	Three 40-mL septum top vials per analysis	Iced HCl to pH<2	14 days for analysis	Fill completely	Federal Express Priority 1	Bubble Wrap or Foam Chips
	TCL SVOC, TCL Pesticides/PCBs	Two 1-L amber glass bottles per analysis	Iced	7 days for extraction 40 days after extraction for analysis	Fill to neck of bottle	Federal Express Priority 1	Bubble Wrap or Foam Chips
	TAL Metals, Dissolved Iron and Manganese	One 1-L polyethylene bottle	HNO ₃ to pH<2	6 months for analysis (mercury - 28 days)	Fill to neck of bottle	Federal Express Priority 1	Bubble Wrap or Foam Chips
	Cyanide	One 1-L polyethylene bottle	Iced NaOH to pH>12	14 days for analysis	Fill to neck of bottle	Federal Express Priority 1	Bubble Wrap or Foam Chips
	Chloride, Sulfate, Alkalinity, Nitrate, Nitrite	Two 1-L polyethylene	Iced	28 days for analysis (alkalinity - 14 days) (nitrate, nitrite - 48 hours)	Fill to neck of bottle	Federal Express Priority 1	Bubble Wrap or Foam Chips
	Dissolved Organic Carbon	One 40-mL septum top vial	Iced, H ₂ SO ₄ to pH<2	28 days for analysis	Fill to neck of bottle	Federal Express Priority 1	Bubble Wrap or Foam Chips
	Sulfide	One 500-mL polyethylene	Iced, 2 mL Zinc Acetate, NaOH to pH>9	7 days for analysis	Fill to neck of bottle	Federal Express Priority 1	Bubble Wrap or Foam Chips
	Ammonia	One 500-mL polyethylene	Iced	28 days for analysis	Fill to neck of bottle	Federal Express Priority 1	Bubble Wrap or Foam Chips

TABLE J-5.1

**CONTAINER, PRESERVATION, SHIPPING AND PACKAGING REQUIREMENTS
REMEDIAL INVESTIGATION/FEASIBILITY STUDY
SOUTH DAYTON DUMP AND LANDFILL
MORaine, OHIO**

<i>Matrix</i>	<i>Analyses</i>	<i>Sample Containers</i> ¹	<i>Preservation</i> ²	<i>Maximum Holding Time from Sample Collection</i> ³	<i>Volume of Sample</i>	<i>Shipping</i>	<i>Normal Packaging</i>
<i>Soil, Sediment</i>	TCL SVOC, Pesticides/PCBs	One 4-oz. glass jar	Iced	14 days for extraction 40 days after extraction for analysis	Fill to shoulder of jar	Federal Express Priority 1	Bubble Wrap or Foam Chips
<i>Soil</i>	TAL Inorganics	One 500-mL glass jar	Iced	6 months for analysis (mercury - 28 days) (cyanide - 14 days)	Fill to shoulder of jar	Federal Express Priority 1	Bubble Wrap or Foam Chips
	TCL VOC	Three 5-gram discrete samplers ⁴	Iced	48 hours for preparation 14 days for analysis	Fill completely	Federal Express Priority 1	Bubble Wrap or Foam Chips
	Geotechnical	Two 500-mL glass jars	None	None	Fill to shoulder of jar	Federal Express Priority 1	Bubble Wrap or Foam Chips

Notes:

- ¹ Where possible, analyses will be combined into the minimum number of sample containers with respect to sample preservation requirements.
- ² Samples requiring refrigeration will be shipped in coolers containing bagged, cubed ice. Following laboratory receipt and log-in, these samples will be stored at 4° ± 2°C.
- ³ Maximum holding times presented are technical holding times and are based on the time elapsed from sample collection.
- ⁴ En Core sampler or equivalent device.

TABLE J-6.1

**FIELD INSTRUMENT CALIBRATION AND QA SUMMARY
SOUTH DAYTON DUMP AND LANDFILL
MORaine, OHIO**

<i>Instrument (1) (Analysis)</i>	<i>Method Reference</i>	<i># Standards Initial Calibration</i>	<i>Acceptance/ Rejection Criteria - Initial Calibration</i>	<i>Frequency of Calibration</i>	<i>Frequency of Initial Calibration Verification</i>	<i>Acceptance/ Rejection Criteria- Initial Calibration Verification</i>	<i>Frequency of Continuing Calibration Verification</i>	<i>Acceptance/ Rejection Criteria- Continuing Calibration Verification</i>	<i>Other Calibration Requirements</i>
YSI 3560 Water Quality Meter (pH, Temperature)	EPA 150.1	2	pH 7.00 buffer ± 0.1 SU	At least daily, or as required (when CCV fails acceptance criteria)	As needed	Same as ICV	Every 10 samples	Same as ICV	None
(Conductivity)	EPA 120.1	NA	NA	Factory-calibrated	Daily	1.000 ± 0.70 mmho	Every 10 samples	1.000 ± 0.70 mmho	None
(ORP)	SM 2580 B	1	NA (ZoBell Solution Cal.)	At least daily, or as required (when CCV fails acceptance criteria)	As needed	± 10 mV	Every 10 samples	Same as ICV	None
YSI 52 (Dissolved Oxygen)	EPA 360.1	1	NA (moist air calibration)	At least daily, or as required (when CCV fails acceptance criteria)	As needed	± 10 %	Every 10 samples	Same as ICV	None
DRT-15C (Turbidity)	NA	NA	Factory-Calibrated	Daily	NA	± 10 %	Every 10	Same as ICV	None
MiniRae Classic PID (Organic Vapors)	NA	2	Instrument-Determined	Daily	NA	NA	Every 10 samples	± 10 %	None
Landtec Gas Extraction Monitor (Landfill Gas)	NA	1	Factory-Calibrated	Daily	As needed	± 10 %	Every 10	Same as ICV	None

Notes:

- (1) Equivalent instruments to those specified may also be used.
 (2) If less than 10 samples are analyzed, a duplicate is still required.
 ICV Initial Calibration verification.
 CCV Continuing Calibration verification.
 SU Standard pH units.

Required
Field QA/QC

Duplicate 1 of every 10 samples. (2)
Duplicate must be ± 0.2 SU of original.

Duplicate 1 of every 10 samples. (2)
Duplicate must be $\pm 15\%$ of original.

Duplicate 1 of every 10 samples. (2)
Duplicate must be ± 10 mV of original.

Duplicate 1 of every 10 samples. (2)
Duplicate must be $\pm 15\%$ of original.

Duplicate 1 of every 10 samples. (2)
Duplicate must be $\pm 15\%$ of original.

None

Duplicate 1 of every 10 samples. (2)
Duplicate must be $\pm 15\%$ of original.

ATTACHMENT J-A
STANDARD FORMS

PAGE _____ OF _____

DRILLING CONTRACTOR _____
 DRILLER _____
 SURFACE ELEVATION _____
 WEATHER (A.M.) _____
 (P.M.) _____

HOLE DESIGNATION _____
DATE/TIME STARTED _____
DATE/TIME COMPLETED _____
DRILLING METHOD _____
CRA SUPERVISOR _____

[illegible]

SOIL CLASSIFICATION SYSTEM (MODIFIED U.S.C.S.)

MAJOR DIVISIONS			GROUP SYMBOL	TYPICAL DESCRIPTION
HIGHLY ORGANIC SOILS			PT	PEAT AND OTHER HIGHLY ORGANIC SOILS
COARSE-GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN NO. 200 SIEVE SIZE)	GRAVELS MORE THAN HALF OF COARSE FRACTION LARGER THAN NO. 4 SIEVE SIZE	CLEAN GRAVELS	GW	WELL GRADED GRAVEL, GRAVEL-SAND MIXTURES, < 5% FINES
			GP	POORLY GRADED GRAVELS AND GRAVEL-SAND MIXTURES, < 5% FINES
		DIRTY GRAVELS	GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES, > 12% FINES
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES, > 12% FINES
	SANDS MORE THAN HALF OF COARSE FRACTION SMALLER THAN NO. 4 SIEVE SIZE	CLEAN SANDS	SW	WELL GRADED SANDS, GRAVELLY SANDS, < 5% FINES
			SP	POORLY GRADED SANDS, OR GRAVELLY SAND, < 5% FINES
		DIRTY SANDS	SM	SILTY SANDS, SAND-SILT MIXTURES > 12% FINES
			SC	CLAYEY SANDS, SAND-CLAY MIXTURES > 12% FINES
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT PASSES NO. 200 SIEVE SIZE)	SILTS BELOW "A" LINE ON PLASTICITY CHART; NEGLECTIBLE ORGANIC CONTENT		ML	INORGANIC SILTS AND VERY FINE SAND, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY
			MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS
	CLAYS ABOVE "A" LINE ON PLASTICITY CHART; NEGLECTIBLE ORGANIC CONTENT		CL	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS
			CI	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS
			CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
	ORGANIC SILTS & ORGANIC CLAYS BELOW "A" LINE ON PLASTICITY CHART		OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
			OH	ORGANIC CLAYS OF HIGH PLASTICITY

CONVENTIONAL SOIL DESCRIPTIONS

NON-COHESIVE (GRANULAR) SOIL

RELATIVE DENSITY BLOWS PER FOOT
(N-VALUE)

Very loose less than 5
Loose 5 to 9
Compact 10 to 29
Dense 30 to 50
Very Dense greater than 50

COHESIVE (CLAYEY) SOIL

CONSISTENCY BLOWS PER FOOT
(N-VALUE)

Very Soft 0 to 2
Soft 3 to 4
Firm 5 to 8
Stiff 9 to 15
Very Stiff 16 to 30
Hard greater than 30

GRAIN SIZE CLASSIFICATION

COBBLES Greater than 3 inches (76 mm)
GRAVEL 3 in. to No. 4 (4.76 mm)
 Coarse Gravel 3 in. to 3/4 in.
 Fine Gravel 3/4 in. to No. 4 (4.76 mm)
SAND No. 4 (4.76 mm) to No. 200 (0.074 mm)
 Coarse Sand No. 4 (4.76 mm) to No. 10 (2.0 mm)
 Medium Sand No. 10 (2.0 mm) to No. 40 (0.42 mm)
 Fine Sand No. 40 (0.42 mm) to No. 200 (0.074 mm)
SILT No. 200 (0.074 mm) to 0.002 mm
CLAY Less than 0.002 mm

NOTE: The "No. ___" refers to the standard sieve sizes.

COMPONENT PERCENTAGE DESCRIPTORS

Noun(s) (e.g. SAND and GRAVEL) 35 to 50%
Adjective (e.g. SANDY) 20 to 35%
With 10 to 20%
Trace Less than 10%

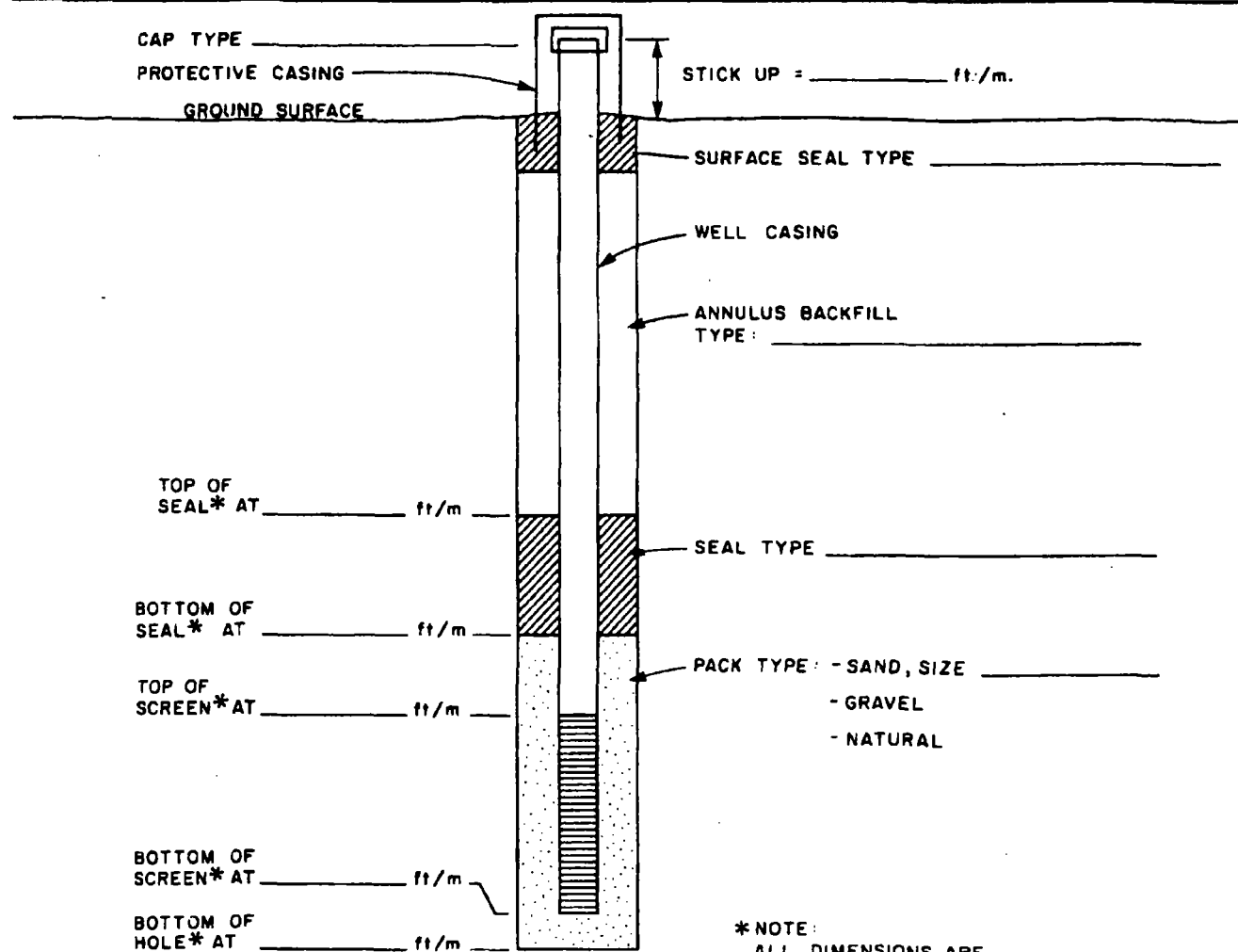
SOIL STRUCTURE TERMS

Stratified Blocky
Laminated Lenses/Seams
Fissured Homogeneous

WELL INSTRUMENTATION LOG

PROJECT NAME: _____
 PROJECT NO: _____
 CLIENT: _____
 LOCATION: _____

HOLE DESIGNATION: _____
 DATE COMPLETED: _____
 DRILLING METHOD: _____
 CRA SUPERVISOR: _____



SCREEN TYPE: ☐ continuous slot ☐ perforated ☐ louvre ☐ other: _____

SCREEN MATERIAL: ☐ stainless steel ☐ plastic ☐ other: _____

SCREEN LENGTH: _____ ft/m SCREEN DIAMETER: _____ in/cm SCREEN SLOT SIZE: _____

WELL CASING MATERIAL: _____ WELL CASING DIAMETER: _____ in/cm

HOLE DIAMETER: _____

DEVELOPMENT: METHOD: _____ DURATION: _____

WELL DEVELOPMENT AND STABILIZATION FORM

PROJECT NAME _____ PROJECT NO. _____
 DATE OF WELL DEVELOPMENT _____
 DEVELOPMENT CREW MEMBERS _____
 SUPERVISOR _____
 PURGING METHOD _____

WELL INFORMATION

WELL NUMBER _____
 WELL TYPE (diameter/material) _____
 MEASURING POINT ELEVATION _____
 STATIC WATER DEPTH _____ ELEVATION _____
 BOTTOM DEPTH _____ ELEVATION _____
 WATER COLUMN LENGTH _____
 SCREENED INTERVAL _____
 WELL VOLUME _____

Note: For 2" diameter well, 1 foot = 0.14 gallons (imp) or 0.16 gallons (us).
 1 meter = 2 liters.

DEVELOPMENT DATA

					TOT/AVG
VOLUME PURGED (# bails/tot. Volume)					
FIELD pH					
FIELD TEMPERATURE					
FIELD CONDUCTIVITY					
CLARITY					
COLOR					
ODOR					
COMMENTS					

COPIES TO: _____

Project Data:

Date: _____
Personnel: _____

Well No.: _____	Screen Length (ft): _____
Measurement Point: _____	Depth to Pump Intake (ft): _____
Constructed Well Depth (ft): _____	Well Diameter, D (in): _____
Measured Well Depth (ft): _____	Well Screen Volume, V_s (mL): _____
Depth of Sediment (ft): _____	Initial Depth to Water (ft): _____

Stabilization Criteria:	±0.1	±3%	±0.005 (<1) ±0.01(>1)	±10	±10%	±10% or (<5)
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ATTACHMENT J-B

FIELD STANDARD OPERATING PROCEDURES

DISSOLVED OXYGEN

Scope and Application: This method is applicable to surface water, wastewater and groundwater.

Method: Potentiometric

Reference: "Methods for Chemical Analysis of Water and Wastes:", EPA-600/4-79-020, revised March 1983, Method 360.1

Sensitivity: 0.1 mg/L as O₂

Optimum Range: 0.1 mg/L to 20 mg/L O₂

Sample Handling: Determined on site

Reagents and Apparatus:

1. Temperature compensated dissolved oxygen (DO) meter, YSI Model 52;
2. DO probe, YSI 5739 Field Probe;
3. DO probe electrolyte solution;
4. DO membrane replacement kit; and
5. Distilled water in wash bottle.

Setting Up DO Sensor:

The sensor is shipped dry and must be filled before use.

1. Unscrew sensor guard, remove o-ring and membrane, and rinse with distilled water.
2. Holding probe in left hand, successively fill the sensor body with electrolyte while pumping the diaphragm with a soft, blunt tool (e.g., pencil eraser). Continue filling and pumping until no more air bubbles appear. Add electrolyte until a large meniscus completely covers the gold cathode.
3. In a single, continuous motion, stretch membrane up, over, and down the sensor. Secure other end of membrane with forefinger.
4. Roll o-ring over probe (do not touch membrane) and trim off excess membrane using scissors or sharp knife.

5. Shake off excess electrolyte and reinstall sensor guard. Store in a humid environment until ready for use.

Calibration in Air:

1. Remove field probe from storage bottle. Switch on meter. Set function switch to O₂-TEMP. Allow meter to equilibrate for at least 15 minutes.
2. Replace probe in storage bottle and switch to CALIBRATE. Press CONFIRM when display reads "Calibrate in percent?".
3. Using up and down arrow keys, adjust the displayed value to correspond to the calibration value determined from the altitude or pressure chart on the back of the meter.
4. When the display has been adjusted to the proper value, press CONFIRM. The display will read "please wait" for a few seconds. The calibration value will then be displayed. The meter is now calibrated.

Procedure:

1. Calibrate meter using calibration procedure.
2. Set selector switch to O₂-TEMP. Slowly lower the probe down monitoring well. Allow probe to equilibrate for 3 to 5 minutes.
3. Gently move the probe up and down at an approximate rate of 1 foot per minute. Observe readings for stability.
4. Record result in the field logbook.
5. Repeat steps 2 through 4 for each sample.

Quality Control:

1. Duplicate 1 out of 10 samples. If less than 10 samples are analyzed, a duplicate is still required. Duplicates must be within 15%.

If the results are outside of the control limits, rinse electrode and repeat analysis. If the results are still outside of the control limits, check calibration and recalibrate if necessary (see item 2, below). If unable to recalibrate, replace sensor membrane.

2. Calibration check results must be within 10% of the true value. Calibration check is performed by measuring DO of humid air in storage bottle (same as calibration

procedure). If the result is outside of 10%, rinse electrodes and check solution again. If still outside the control limit, recalibrate the meter and reanalyze all samples analyzed since the last in control calibration.

3. Only distilled water is to be used for probe rinsing prior to analyses.

Interferences:

Interferences in DO measurements generally occur due to membrane coating. Clean probe as specified in the sensor manual.

The presence of other gases such as chlorine, nitrous and nitric oxide, hydrogen sulfide and sulfur dioxide interfere with DO measurements. The sulfur based compounds will tarnish the electrodes resulting in sluggish or erratic measurements. Polishing the electrodes as specified in the operating manual will restore the performance of the meter. Recalibrate meter before analysis of next sample.

GAS EXTRACTION MONITOR

Scope and Application: This method is applicable to screening methane, carbon dioxide, and oxygen content in landfill gas.

Method: Infrared Gas Analyzer

Sensitivity: ±1 percent methane by volume
±1 percent carbon dioxide
±1 percent oxygen by volume

Optimum Range: 0 to 100 percent methane
0 to 100 percent carbon dioxide
0 to 25 percent oxygen

Sample Handling: Determined on site

Reagents and Apparatus:

1. Landtec Gas Extraction Monitor, GEM-500;
2. Calibration gas (commercially available standard cylinders containing methane, carbon dioxide, oxygen);
3. Calibration apparatus and tubing; and
4. Battery chargers.

Setting Up Gas Extraction Monitor:

1. Ensure the inlet filter is clean by using an Allen key to unscrew the inlet port from the instrument body. Replace inlet filter if needed.
2. Thread the inlet port back into the instrument body and tighten.
3. Check to ensure the sample hose's filter/ water trap assembly is clean by disassembling the threaded plastic housing. Replace the filter if needed. Re-thread the plastic housing back together and tighten.

Field Calibration in Procedure:

1. Turn the instrument on by pressing the "Red" button. Press button [0] to exit the MAIN MENU Screen. Press button [1] to enter the GENERAL UTILITIES Screen.
2. Press button [9] for more OPTIONS. Press button [5] for GAS CALIBRATION Screen.

3. Press button [1] to enter the ZERO METHANE Screen. Ensure the instrument is in fresh air.
4. Press button [5] to turn on the GEM-500 sample pump, let purge for approximately 1 minute.
5. Press button [1] to perform the instrument ZERO calibration. If "CH₄ Not Zeroed" was displayed, ensure the instrument is in clean air and re-zero the instrument. If "CH₄ Zeroed" appeared on the display, press the [0] button twice to return to the GAS CALIBRATION Screen.
6. Press button [3] to enter the O₂ CALIBRATION Screen. Press button [2] to calibrate O₂ Span Screen.
7. Press button [5] to turn on the GEM-500 sample pump, let purge for approximately 1 minute.
8. Press button [1] and input the oxygen concentration of the atmosphere (20.8 percent) on keyboard of the GEM-500.
9. Press button [1] to confirm the calibration.
10. Press button [0] until the MAIN MENU Screen appears. The instrument is ready for field use.

Procedure:

1. Connect GEM-500 to a "T" connector of the gas probe so as to measure methane concentration. The "T" connection will be connected to the sample port. Record initial readings for the GEM-500. The valve will then be closed and the "T" connection removed from the gas probe.
2. A personal sampling pump will be added to the sampling train with its intake connected to the sample port and its discharge connected to the "T" connector (GEM-500 is still connected to the "T" connection). The personal sampling pump will be turned on and operated at a low flow rate. Readings will be collected every 30 seconds.
3. Readings will be collected until three consecutive readings are recorded that are within 10 percent of the average of the last three readings. If the aforementioned stabilization criteria cannot be attained, then readings will be recorded until such time as a maximum of five readings have been collected.
4. Configure GEM-500 so as to measure oxygen concentration and record reading in the field logbook.

5. Configure GEM-500 so as to measure carbon dioxide concentration and record reading in the field logbook.
6. Disconnect personal pump from sampling port. The sampling train will continue to operate for a period of 1 minute, drawing in ambient air, to purge the train of sample.
7. Repeat steps 1 through 6 for each sample.

Quality Control:

1. Calibration check results must be within 10 percent of the true value. If the result is outside of 10 percent, recalibrate the instrument s specified above. Record the calibration standard in the field logbook.
2. Duplicate samples are not analyzed since the headspace readings will vary considerably as volatilization in the soil occurs.

Interferences:

In the event that the GEM-500 is operating during the winter months, the instrument will be stored and maintained in an ambient temperature operating range between 10°F and 104°F.

STANDARD OPERATING PROCEDURE FOR HOLLOW-STEM LEAD-SLOT AUGER BOREHOLE ADVANCEMENT AND SAMPLE COLLECTION

The SOP for the hollow-stem lead-slot auger for investigation within the Disposal Areas is as follows:

1. The drill rig, augers, cutting bits, and associated equipment will be decontaminated prior to starting and between boreholes following procedures in Section J 7.2 of the FSP. All split-spoons and sampling equipment will be decontaminated between samples following procedures in Section J 7.1 of the FSP
2. The drill rig is set up at the drilling location.
3. The boring is advanced from waste material surface using 4.25-inch inside diameter hollow-stem augers. The lead auger is a slotted auger.
4. Continuous waste material samples will be collected using 3-inch outside diameter split-spoons to the bottom of waste. During borehole advancement, leachate fluid sampling and NAPL level monitoring will be. At the waste material/native soils contact, DNAPL field screening will be conducted.
5. Following the collection of the DNAPL screening sample noted above, the borehole will be advanced into native material. Continuous soil samples will be collected during borehole advancement using a 2-inch outside diameter split-spoon.
6. Once the water table within the upper aquifer has been encountered, groundwater samples will be collected at 10-foot intervals beginning no deeper than 5 feet below the top of the water table. The water table position in each borehole will be determined through the visual examination of split-spoon soil samples for saturated conditions and the measurement of water levels within the hollow-stem augers.

Where the water table is coincident with the leachate level or with the waste material/native soils contact, vertical aquifer sampling will begin at five feet below the waste material/native soils contact.

Groundwater samples will be collected by means of a Grundfos (or equivalent) submersible pump. The pump assembly would consist of the pump and an inflatable packer attached to stainless steel riser pipe. The purpose of the packer is to isolate the lead-slot auger from the water column above it. The pump/packer assembly will be lowered into the annulus of the hollow-stem augers such that the pump is near the mid-point of the lead auger with the packer at the top of the lead-slot auger. At each sample interval, approximately 3 to 5 lead-slot auger volumes of groundwater will be purged prior to sample collection (the slotted auger volume is approximately 4 gallons). The purge rate will not exceed 2 gallons per minute. The number of auger volumes purged will be determined by comparing the results of the field parameters after each volume. The groundwater will be considered stable after a maximum of five auger

volumes are removed or when three successive readings for pH, specific conductance, and temperature agree within the following limits:

pH	± 0.1 pH unit
Specific conductance	± 10 µmhos (temperature corrected)
Temperature	± 1.0 °C

Following the completion of purging of each sample interval, the pump flow rate will be reduced to the lowest sustainable flow rate.

7. Collect a groundwater sample for vertical profiling as per procedures presented in Section J 2.2.1 of FSP utilizing the low flow rate discharge from the submersible pump for collecting the sample. The groundwater sample for each interval will be collected directly from the pump discharge into the sample containers. The groundwater samples will be handled, stored, and analyzed consistent with the procedures in Section J2.2.5 of the FSP.
8. Following the collection of each groundwater sample, the pump/packer assembly will be removed from the annulus of the hollow-stem augers. The pump/packer assembly will be decontaminated between samples following procedures in Section J 7.1 of the FSP.
9. Upon completion of borehole advancement and upper aquifer VAS, the borehole will be filled with bentonite grout (Aqua Guard or Quik-Grout) emplaced via a tremie pipe while withdrawing the augers from the borehole.

Procedures for related activities were previously provided in Appendix W of the Addendum to the RI/FS Work Plan and include:

- Decontamination (Section J 7.0);
- Handling of Investigation Derived Waste (Section J 8.0);
- Field Quality Control Sampling (Section J 4.0);
- Sample Custody and Document Control (Section J 5.0); and
- Field Calibration, Preventative Maintenance, and Standard Operating Procedures (Section J 6.0).

TURBIDITY

<u>Scope and Application:</u>	This method is applicable to surface water, wastewater and groundwater.
<u>Method:</u>	Nephelometric
<u>Reference:</u>	"Methods for Chemical Analysis of Water and Wastes:", EPA-600/4-79-020, revised March 1983, Method 180.1
<u>Sensitivity:</u>	0.01 Nephelometric Turbidity Unit (NTU)
<u>Optimum Range:</u>	0 - 20; 0 - 200 NTU
<u>Sample Handling:</u>	Determined on site

Reagents and Apparatus:

1. Direct reading turbidity meter, HF Scientific Model DRT-15C;
2. Cuvettes with screw tops;
3. Battery charger;
4. 0.02 NTU (nominal) reference standard; and
5. Distilled or deionized water in wash bottle.

Calibration Check and Operation

The turbidimeter has been calibrated by the manufacturer and electronic calibration using freshly prepared formazin standards should only be performed if the electronic printed circuit board, the photodetectors or the light source has been replaced. The calibration procedure is presented in pages 5 and 6 of the operating manual (attached).

The procedures for calibration checks and the operation of the meter follows:

1. For accurate measurements in the low range rotate the cuvettes in the well to obtain the minimum reading. Mark the cuvette with one of the adhesive dots provided with the instrument so that orientation of the cuvette will be identical each time it is placed in the instrument.
2. To operate the turbidimeter, switch to the "20" range and place the Reference Standard (0.02 NTU) in the optical well.
3. With the light shield in place over the well, adjust the Reference Adjust knob to cause the meter to read the reference standard value on the scale. The unit is now ready for use in either range.

4. To make a measurement of a sample, clean one of the cuvettes and fill to within approximately 1/2" of top with sample. Place the top on the cuvette and carefully clean the outside surface of the cuvette with a lint free wiper such as KimWipes. Place the sample in the well and place the light shield over the well. Select the appropriate range for best readability. Record results in field logbook.
5. Repeat steps 3 and 4 for each sample.

Quality Control:

1. Duplicate 1 out of 10 samples. If less than 10 samples are analyzed, a duplicate is still required. Duplicates must be within $\pm 15\%$.

If the results are outside of the control limits, clean cuvettes and repeat analysis. If results are still outside of the control limits, recollect samples and repeat analysis. If the results are still outside of the control limits, check calibration and recalibrate if necessary (see item 2, below).

2. Calibration check results must be $\pm 10\%$ of the true value. If the result is outside of $\pm 10\%$, clean cuvettes and check solution again. If still outside the control limit, recalibrate the meter and reanalyze all samples analyzed since the last in-control calibration.
3. All glassware is to be soap and water washed, tap rinsed and distilled or deionized water rinsed prior to analyses.

Interferences:

Interferences in turbidity measurements are generally due to dirty or scratched cuvettes. Handle only the top one-third of the cuvettes and wipe clean using a lint-free wiper (KimWipes or equivalent).

OXIDATION-REDUCTION POTENTIAL (ORP)

Scope and Application: This method is applicable to surface water, wastewater and groundwater.

Method: Potentiometric

Reference: "Standard Methods for the Examination of Water and Wastewater", APHA, 18th edition, 1992, Method 2580B.

Sensitivity: 1 mV

Optimum Range: -1,500 to 1,500 mV

Sample Handling: Determined on site

Reagents and Apparatus:

1. ORP meter, YSI Model 3560 Water Quality Monitor;
2. ORP electrode assembly, YSI Model 3540;
3. Thermilinear thermistor temperature probe, YSI Model 3510;
4. ZoBell Solution, YSI Model 3682; and
5. Distilled or deionized water in wash bottle.

Calibration:

1. Turn on the YSI 3500 Water Quality Monitor and set the pH function switch to mV.
2. Connect the shorting cap attached to the 3500 to the mV input jack. The display should read 000 ± 2 mV. This indicates that the 3500 electronics are zeroed.
3. Detach the shorting cap and connect the 3540 to the mV input jack. If a pH electrode is not attached to the pH input jack, connect the shorting cap to it.
4. Attach the 3510 to the TEMP input jack.
5. Rinse the 3540 and 3510 with distilled or deionized water, followed by a rinse with a small amount of reconstituted YSI 3682 ZoBell Solution.
6. Half fill a disposable 50 mL sample cup with ZoBell Solution and fully immerse the bulb of the 3540 and the end of the sheath of the 3510. Allow the sensors to equilibrate, and note the reading.

7. The displayed mV values is not temperature compensated and should be corrected to 25°C at 1.3 mV/°C. The temperature coefficient is in reverse proportion to the temperature.
8. Correct the value to 25°C using the following equation:
$$\text{Actual Value mV} = \text{Display Value} + [(\text{Display Temp.} - 25^{\circ}\text{C}) \times (1.3 \text{ mV})]$$

Procedure:

1. Calibrate meter using calibration procedure.
2. Set up meter as outlined in the instruction manual.
3. Record temperature and ORP of the sample in the field logbook.
4. Correct ORP to 25°C using the formula presented above.
5. Record corrected ORP in the field logbook.
6. Repeat steps 3 through 6 for each sample.
7. Recheck calibration with ZoBell solution after every ten or fewer samples and after the last sample.
8. Store electrode in soaker bottle when not in use.

Quality Control:

1. Duplicate 1 out of 10 samples. If less than 10 samples are analyzed, a duplicate is still required. Duplicates must be ± 10 mV.

If the results are outside of the control limits, rinse electrodes and repeat analysis. If results are still outside of the control limits, recollect samples and repeat analysis. If the results are still outside of the control limits, check calibration and recalibrate if necessary (see item 2, below). If drift is suspected to be the cause of the problem, clean the electrode and recalibrate. If drift is still apparent, replace electrode.
2. Calibration check results must be 231 ± 10 mV. If the result is outside of this range, rinse electrodes and check solution again. If still outside the this range, recalibrate the meter and reanalyze all samples analyzed since the last in-control calibration.

Interferences:

Interferences in ORP measurements occur when the platinum electrode surface becomes coated. Clean the ORP electrode as follows:

1. Soft coatings should be removed by use of a wash bottle of water or by gently wiping with a soft cloth. Remove the bulb guard if necessary. Be careful not to scratch the platinum.
2. Hard coatings or organic chemicals should be removed by an appropriate chemical solvent, by gently scrubbing with a very fine cleansing powder such as "Softscrub", or by gently polishing with 600 grade wet silicon carbide paper. Wet a piece of the paper with water and gently polish the electrode with a circular twisting motion.

Note:

After cleaning the platinum surface, soak the electrode for a 8 to 24 hours in 4.0 pH buffer, then recheck it with YSI 3682 ZoBell Solution before further use.

pH/TEMPERATURE

Scope and Application: This method is applicable to surface water, wastewater and groundwater.

Method: Potentiometric

Reference: "Methods for Chemical Analysis of Water and Wastes:", EPA-600/4-79-020, revised March 1983, Method 150.1

Sensitivity: 0.01 pH unit; 0.1°C

Optimum Range: pH 1.00 to 12.00; temperature -5 to 50°C

Sample Handling: Determined on site

Reagents and Apparatus:

1. Temperature compensated pH meter, YSI Model 3560 Water Quality Monitoring System;
2. Combination pH electrode YSI Model 3530;
3. Thermilinear thermister YSI Model 3510 temperature probe;
4. pH buffer solutions, pH 4.00, 7.00, and 10.00 (certified buffer solutions); and
5. Distilled or deionized water in wash bottle.

Calibration:

1. Switch On/Off key to On. Before connecting the pH electrode, zero the electronics with the shorting cap attached to the meter. Turn on the meter and set the pH function switch to pH. Connect the shorting cap to the pH input jack and set the manual temperature compensation knob to 25°C. Adjust the CAL control to indicate 7.00 ± 0.01 on the pH-mV display. Disconnect the shorting cap from the pH input and connect it to the mV input jack. The monitor is now zeroed.
2. Test the 3530 pH electrode for noise and offset as follows: Rinse the 3530 and the YSI 3510 Temperature Probe with pH 7.00 buffer to remove any contaminants. Connect the 3530 to the pH input jack and the 3510 to the TEMP input jack. Pour pH 7.00 buffer into a 50 mL sample cup then immerse both of the sensors into the buffer at $25.0 \pm 0.1^\circ\text{C}$ (use the °C display to confirm the temperature). Allow the sensors to equilibrate. A display value other than 7.00 shows electrode background noise and offset. The 3530 background noise and offset at pH 7.00 should not exceed ± 0.2 pH units at 25°C. Replace pH probe if background noise exceeds this tolerance.

3. Set the function switch to pH ATC. Connect the 3510 to the pH ATC input jack. While the 3510 can be used in either location, the pH ATC function will not work unless the 3510 is connected to the pH ATC input.
4. Rinse the 3530 and a YSI 3510 Temperature Probe with pH 7.00 buffer to remove any contaminants. Connect the 3530 to the pH input jack and the 3510 to the TEMP input jack. Pour pH 7.00 buffer into a 50 ml sample cup, immerse both of the sensor into the buffer. Allow the sensors to equilibrate in the buffer until a stable reading is obtained. Read the temperature and adjust the pH manual temperature compensation knob to the same value. Adjust the CAL control knob for 700 ± 0.01 pH units in the display and discard the buffer. Rinse the sensors with deionized or distilled water, followed by a rinse of the next desired buffer (typically pH 4.00 or 10.00). Half fill another disposable 50 ml sample cup with the next buffer for calibration and immerse the sensors. Allow the sensors to equilibrate until a stable reading is obtained. The temperature of the two buffers should not differ by more than $\pm 0.1^\circ\text{C}$. Adjust the SLOPE control until the display is within 0.01 pH units of the buffers stated value. Discard the buffers. The pH system is now calibrated and ready for use.

Procedure:

1. Calibrate meter using calibration procedure.
2. Set up meter as outlined in the operating manual.
3. Pour the sample into clean sample jar or plastic cup.
4. Record temperature and pH of the sample in the logbook.
5. Rinse with water and pH 7.00 buffer.
6. Repeat steps 3 through 5 for each sample.
7. Recheck calibration with pH 7.00 buffer solution after every 10 or fewer samples and after the last sample.
8. Store pH electrode in soaker bottle when not in use.

Quality Control:

1. Duplicate 1 out of 10 samples. If less than 10 samples are analyzed, a duplicate is still required. Duplicates must be ± 0.2 pH units.

If the results are outside of the control limits, rinse electrodes and repeat analysis. If results are still outside of the control limits, recollect samples and repeat analysis. If the results are still outside of the control limits, check calibration and recalibrate if necessary (see item 2, below). If drift is suspected to be the cause of

the problem, clean the electrode and recalibrate. If drift is still apparent, replace electrode.

2. Calibration check results must be ± 0.10 pH unit of the true value. If the result is outside of ± 0.10 pH unit, rinse electrodes and check solution again. If still outside the control limit, recalibrate the meter and reanalyze all samples analyzed since the last in-control calibration.
3. All glassware is to be soap and water washed, tap water rinsed and distilled or deionized water rinsed prior to analyses.

Interferences:

Interferences in pH measurements occur with presence of weak organic and inorganic salts and oil and grease. If oil and grease are visible, note in logbook. Clean electrode with soap and water, followed by 10% HCl and deionized water rinse. Recalibrate meter before analysis of next sample.

STANDARD OPERATING PROCEDURE FOR ROTOSONIC DRILLING METHOD (VERTICAL AQUIFER SAMPLING AND MONITORING WELL INSTALLATION)

The locations outside of Disposal Areas were previously investigated for stratigraphy via CPT methods and are undergoing vertical aquifer sampling by Geoprobe™ (or equivalent) methods.

A. Boreholes Outside of Disposal Areas

At each borehole location beyond the limits of the Disposal Areas, a nominal 6-inch diameter borehole will be advanced to a minimum depth of 100 feet below ground surface. In areas of significant groundwater impact, a temporary 7-inch diameter steel casing will be pushed into the upper prior to advancing the 6-inch diameter borehole into the lower aquifer. The requirement for a temporary 7-inch diameter casing will be based upon the results of the upper aquifer VAS. Continuous soil sampling will be conducted from ground surface to the termination of the borehole.

At each borehole location, rotosonic VAS will begin at a depth below the termination point of the Geoprobe™ (or equivalent) VAS work, beginning at 10 feet below the deepest Geoprobe™ (or equivalent) VAS sample depth. At locations where only the upper aquifer has been investigated, the rotosonic VAS will begin 5 feet into the lower aquifer and will continue at 10 foot intervals.

Full details of the rotosonic borehole advancement and VAS procedures are described in Sections C and D of this SOP.

Monitoring wells may be installed in selected rotosonic boreholes following procedures outlined in Section J 2.2.1.2 of the FSP.

B. Boreholes Within Disposal Areas

At the proposed rotosonic/hollow-stem auger borehole locations within the Disposal Areas, the hollow-stem auger borehole and upper aquifer VAS will be completed prior to commencing the rotosonic VAS. At each borehole location within the Disposal Areas, continuous rotosonic soil and waste sampling will be conducted from the surface of the waste material to a minimum depth of 100 feet below ground surface, and continuing below 100 feet wherever that may be necessary to complete VAS sampling. At each borehole location, rotosonic VAS will begin at 5 feet into the lower aquifer and continue at 10-foot intervals.

Full details of the Rotosonic borehole advancement and VAS procedures are described in Sections C and D of this SOP.

Monitoring wells will not be installed in rotosonic boreholes within the Disposal Areas.

C. Rotosonic Borehole Advancement

1. The drill rig, drill pipe, cutting bits, and associated equipment will be decontaminated prior to starting and between boreholes following the procedures outlined in Section J 7.2 of the FSP. All sampling equipment will be decontaminated between samples following procedures outlined in Section J 7.1 of the FSP.
2. The drill rig is set up at the drilling location.
3. The inner core barrel (nominal 4-inch diameter) is advanced 10 feet into the ground without the use of drilling fluids or air.
4. The inner core barrel is removed from the borehole, the sample extruded from the core barrel by vibratory action and placed directly into 5 feet long sealed cylindrical plastic sleeves. The borehole may collapse partially or fully when the core barrel is removed. The soil samples are field screened with a PID and representative soil samples collected for geologic record and soil physical property analyses following procedures outlined in Section J2.2.1.2 of the FSP.
5. The inner core barrel is re-advanced to the previously sampled depth. The 6-inch diameter outer casing is advanced to the same depth. If required, water is injected into the annulus between the 6-inch diameter casing and the 4-inch diameter core barrel to control heaving sands. The volume of water injected during the advancement of the 6-inch casing will be measured using an accurate metering device. Typically only a few gallons are lost to the formation during advancement of the outer casing. The inner core barrel is removed and cleaned out if necessary, if the borehole collapsed after the sample was collected. A fluid head is maintained within the outer casing during removal of the inner core barrel. Some of this fluid may be lost to the underlying formation material.
6. The inner core barrel (nominal 4-inch diameter) is advanced another 10 feet into the ground and the sample collected as noted in Step 4.
7. Continue borehole advancement in 10-foot intervals.

D. Rotosonic Vertical Aquifer Sampling

Vertical Aquifer Sampling will be conducted in the lower aquifer at depth intervals as described in Section 2.2.1.2 of the FSP, at 10-foot intervals beginning 5 feet into the lower aquifer. At locations where the CPT VAS (collected using the Geoprobe™ (or equivalent) VAS methodology as previously approved by Ohio EPA) has extended into the lower aquifer, the rotosonic VAS will begin at 10 feet below the deepest location previously sampled.

1. The inner core barrel is removed. The interval for groundwater sampling is selected based on the review of the extracted core. A groundwater sampling assembly (i.e., temporary well) is installed to the required depth. The temporary well consists of a 5-foot length of

No. 10 slot, 2-inch diameter stainless steel screen coupled to a suitable length of 2-inch diameter stainless steel riser pipe. An inflatable packer is attached to the top of the screen and is used to seal the inside of the 6-inch diameter outer casing from the formation (see attached figure provided by Bowser-Morner). If necessary due to borehole collapse, the temporary well will be pushed and/or vibrated to the required depth.

2. A Grundfos, or equivalent, 2-inch diameter submersible pump, attached to ½-inch diameter polyethylene tubing, is installed into the temporary well and set in the upper portion of the screened interval.
3. In order to collect representative water samples, the volume of water added during the preceding 10-foot advancement of the outer casing will be removed and a further three to five well volumes will be removed prior to sample collection (one well volume equals the number of feet of water within the screen and riser pipe times 0.161 gallons per foot). The water level will be measured within the 2-inch diameter riser pipe using a water level tape (Solinst Model 101 or equivalent) in order to determine well volume. The depth to the bottom of the screen is known.
4. Water samples will be collected and checked following each purged well volume for field measured parameters in order to show stability. The number of well volumes purged will be determined by comparing the results of the field parameters after each well volume. The groundwater will be considered stable after a maximum of five well volumes are removed or when three successive readings for pH, specific conductance, and temperature agree within the following limits:

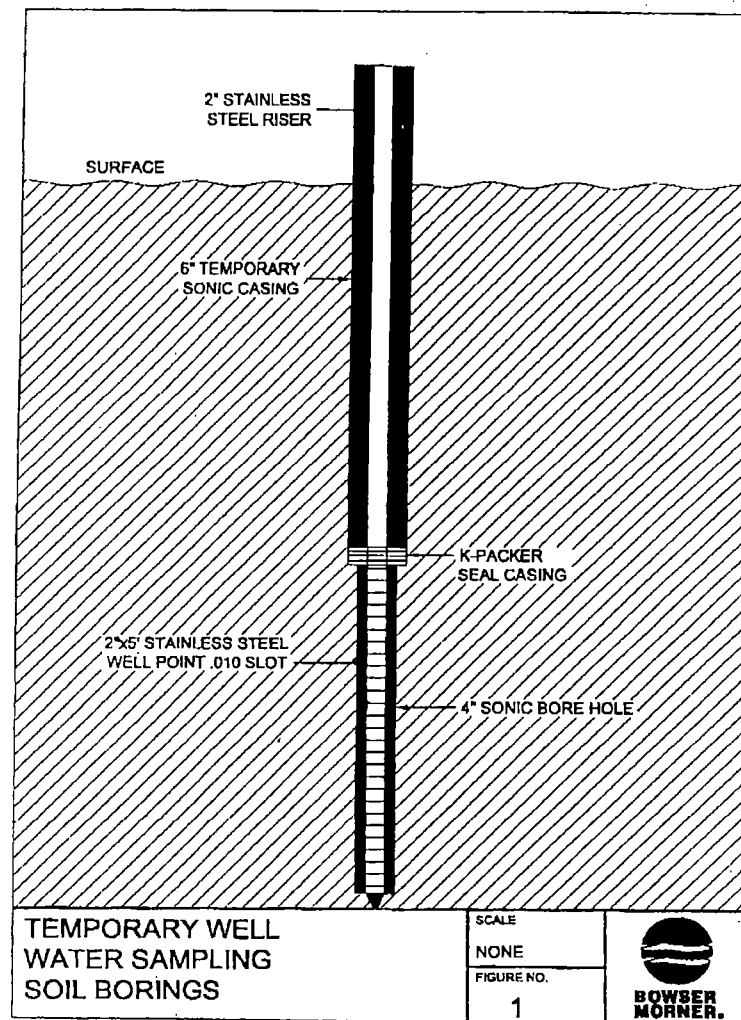
pH	± 0.1 pH unit
Specific conductance	± 10 µmhos (temperature corrected)
Temperature	± 1.0 °C

The flow rate for purging of groundwater would be dependent on the capacity of the submersible pump and the transmissivity of the aquifer material. The maximum purge rate would be approximately 2 gallons per minute. Upon purging of the required screen volumes, the flow rate would be reduced to the lowest sustainable flow rate and sampling would be conducted after purging at least one sample tubing volume (1/2-inch tubing volume = 0.010 gal/foot). In addition, in order to aid in the verification of groundwater stability, stabilization measurements will be compared against the data from the lower aquifer recorded during recent groundwater sample collection activities.

5. Collect a groundwater sample for vertical profiling as per procedures presented in Section J 2.2.5 of the FSP utilizing the low flow rate discharge from the submersible pump for collecting the sample. The groundwater sample for each interval will be collected directly from the pump discharge into the sample containers. The groundwater samples will be handled, stored, and analyzed consistent with the procedures in J 2.2.5 of the FSP.
6. Remove the temporary well from the outer casing and resume borehole advancement. The temporary well materials will be decontaminated between each sample following procedures outlined in Section J 7.2 of the FSP. The Grundfos pump and tubing will be

decontaminated between samples following procedures in Section J 7.1 of the FSP. If the polyethylene tubing becomes damaged or soiled beyond readily decontaminated conditions (i.e., purging of NAPL through the tubing) the tubing will be replaced.

7. Upon completion of borehole advancement and lower aquifer VAS, the borehole will be filled with bentonite grout (Aqua Guard or Quik-Grout) emplaced via a tremie pipe while withdrawing the outer casing from the borehole. If used, the temporary 7-inch steel casing will also be removed at this time.



CONDUCTIVITY

Scope and Application: This method is applicable to surface water, wastewater and groundwater.

Method: Specific Conductance

Reference: "Methods for Chemical Analysis of Water and Wastes"
EPA-600/4-79-020, revised March 1983, Method 120.1

Sensitivity: 0.1 mmhos/cm

Optimum Range: 0 - 100.0 mmhos/cm

Sample Handling: Determine on site

Reagents and Apparatus:

1. Conductivity meter - YSI Model 3560 Water Quality Monitoring System;
2. Conductivity Cell - YSI Model 3520 Flow-Through Conductivity Cell (K=5/cm);
3. Thermilinear Thermister - YSI Model 3510 Temperature Probe;
4. Deionized water; and
5. Conductivity standard, 1.0 mmhos/cm @25°C - YSI Model 3167.

Notes:

The conductivity meter is factory calibrated. The calibration is checked using a solution of known conductance.

Calibration Check

Connect the 3520 cell and a 3510 Temperature Probe to the 3500, and remove them from the sample chamber. Set the conductivity function switch to 2 ATC. Rinse the inside and outside of the cell and the probe with about 1/3 the content of the 3167 bottle. Place both of the sensors into the remainder of the solution in the bottle and allow them to come to temperature equilibrium. Make sure that the 3250 body is immersed so that the liquid level is half way up the knurled portion of the cell. Read the displayed value and determine if the cell/instrument is within specified accuracy. The displayed value is corrected to 25°C automatically and should be 1.000 ±0.070 mmhos/cm. If the value is not within specification replace 3250 cell.

Procedure:

1. Check calibration of meter.
2. Set up meter as outlined in the operating manual.
3. Before any conductivity cell is used, it should be soaked in distilled or deionized water for at least one hour. To make conductivity measurements, connect a YSI 3520 Flow-Through Conductivity Cell to the 3500. Set the conductivity function switch to 2 and observe the displayed value after the reading is stable. The display reads out in mmhos/cm.
4. If the overrange signal (1. _____) is displayed, the conductivity of the water being measured is greater than 1.999 mmhos/cm. Reset the function switch to 20. If the overrange signal is still displayed, reset to 100. If the overrange signal is still displayed, either the conductivity is greater than 100.0 mmhos/cm and the YSI 3500 Water Quality Monitor can not be used for conductivity determinations.
5. Record conductance readings in field logbook.
6. Repeat steps 3 through 5 for remaining samples.

Quality Control:

1. The quality control calibration check standard must be analyzed initially, after every 10 or fewer samples and after the last sample. If less than 10 samples are analyzed, the calibration standard is still required to be analyzed. The standard must be within ± 10 percent of the true value or the samples run after the last acceptable check standard are to be reanalyzed. Record the calibration standard in the field logbook.
2. Duplicate a minimum of 1 out of 10 samples. If less than 10 samples are analyzed, a duplicate is still required. Duplicate values are to be within $\pm 15\%$ of each other. If outside of this range, reanalyze the samples. If still outside the acceptance range, recollect sample and reanalyze. If still out, replace probe.

SOIL VOC SCREENING

Scope and Application: This method is applicable to screening VOCs in the headspace of soil samples.

Method: Photoionization

Sensitivity: Approximately 0.5 ppm depending on background

Optimum Range: Background to 2,000 ppm

Sample Handling: Determined on site

Reagents and Apparatus:

1. Mini Rae Classic Photoionization Detector (PID);
2. Calibration gas (commercially available standard cylinders containing isobutylene);
3. Calibration apparatus and tubing; and
4. Battery chargers.

Procedure:

1. Calibrate meter using the instrument manufacturer's calibration procedure attached.
2. The samples for VOC headspace screening will be prepared in the field by filling a 2- or 4-ounce soil jar to one-half its volume and sealing with a teflon-lined closure. Alternately, a polyethylene bag with zipper-type closure (e.g., Ziploc brand) may be used. The remaining sample will be placed in the appropriate jars for the analyses required.
3. Allow the sample for VOC headspace screening to remain at ambient temperature for a minimum of 10 minutes. This will allow for VOCs in the soil to reach equilibrium in the headspace of the container.
4. Remove the lid of the soil jar or open the bag slightly and insert the probe of the meter into the headspace.
5. Take the highest reading from the meter or readout of the instrument.
6. Record the reading in the field logbook.
7. Recheck calibration with calibration gas after a minimum of every 10 samples and after the last sample.

Quality Control:

1. Calibration check results must be ± 10 percent of the true value. If the result is outside of ± 10 percent, recalibrate the meter as specified above.
2. Duplicate samples are not analyzed since the headspace VOC readings will vary considerably as the soil VOCs volatilize.

Interferences and Limitations:

Humid conditions will cause a negative bias to the reading. The photoionization detection principle used by the instruments will not detect all VOCs. The instrument is most sensitive to aromatic, alkene and alkyne VOCs.

TOXIC VAPOR ANALYZER

Scope and Application: This method is applicable to screening methane and organic vapors in soil gas probes.

Method: Photoionization/Flame Ionization

Sensitivity: ± 25 percent of reading or ± 2.5 ppm, whichever is greater

Optimum Range: 0.5 to 500 ppm (photoionization)
1.0 to 10,000 ppm (flameionization)

Sample Handling: Determine on site

Reagents and Apparatus:

1. Foxboro TVA - 1000B Toxic Vapor Analyzer;
2. Calibration gas (commercially available standard cylinders containing zero gas and 500 ppm methane gas);
3. Calibration apparatus and tubing; and
4. Battery charger.

Procedure:

1. Connect the sample probe (electrical and sample line connections) to the appropriate receptors on the TVA-1000B.
2. Calibrate analyzer using the instrument manufacturer's calibration procedure on page 19 in Attachment A.
3. Monitoring with the TVA-1000B will be performed while traversing grid lines spaced 30 meters apart as specified in the Section 5.0 of the Work Plan.
4. The vapor concentration may be read immediately on either two displays - one mounted directly on the hand-held sample probe an the other on the instrument side pack itself.
5. Both FID and PID readings will be displayed and logged simultaneously, the relative response of the two detectors may indicate the identity of the compound being measured. For example, the PID will not respond to methane, but the FID responds very well. Therefore, a high FID reading with virtually no PID response might indicate the presence of methane. Consequently, PIDs respond very well to some inorganic gases that FIDs cannot detect. Therefore, a high PID reading with no FID reading suggests the presence of an inorganic compound.

6. Readings will be made at approximately 2-meter intervals by placing the probe inlet within 5 to 10 centimeters of the ground surface.
7. Record all readings in the field logbook.

Quality Control:

1. Calibration check results must be ± 10 percent of the true value. If the results is outside of ± 10 percent, recalibrate the meter as specified above. Record the calibration standard in the field logbook.
2. Duplicate samples are not analyzed since the headspace methane and VOC readings will vary considerably as volatilization in the soil occurs.

Interference and Limitations:

Normal operating conditions require ambient temperature range between 32°F and 104°F, relative humidity range for FID is 20 to 95 percent and for PID it is 20 to 70 percent, noncondensing.

ATTACHMENT J-C

ASTM METHODS



Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils¹

This standard is issued under the fixed designation D 1586; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This test method describes the procedure, generally known as the Standard Penetration Test (SPT), for driving a split-barrel sampler to obtain a representative soil sample and a measure of the resistance of the soil to penetration of the sampler.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific precautionary statement, see 5.4.1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

NOTE 1—Practice D 6066 can be used when testing loose sands below the water table for liquefaction studies or when a higher level of care is required when drilling these soils. This practice provides information on drilling methods, equipment variables, energy corrections, and blow-count normalization.

2. Referenced Documents

2.1 ASTM Standards:

- D 2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)²
- D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)²
- D 4220 Practices for Preserving and Transporting Soil Samples²
- D 4633 Test Method for Stress Wave Energy Measurement for Dynamic Penetrometer Testing Systems²
- D 6066 Practice for Determining the Normalized Penetration Resistance Testing of Sands for Evaluation of Liquefaction Potential³

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *anvil*—that portion of the drive-weight assembly

which the hammer strikes and through which the hammer energy passes into the drill rods.

3.1.2 *cathead*—the rotating drum or windlass in the rope-cathead lift system around which the operator wraps a rope to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.

3.1.3 *drill rods*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.1.4 *drive-weight assembly*—a device consisting of the hammer, hammer fall guide, the anvil, and any hammer drop system.

3.1.5 *hammer*—that portion of the drive-weight assembly consisting of the 140 ± 2 lb (63.5 ± 1 kg) impact weight which is successively lifted and dropped to provide the energy that accomplishes the sampling and penetration.

3.1.6 *hammer drop system*—that portion of the drive-weight assembly by which the operator accomplishes the lifting and dropping of the hammer to produce the blow.

3.1.7 *hammer fall guide*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.1.8 *N-value*—the blowcount representation of the penetration resistance of the soil. The *N-value*, reported in blows per foot, equals the sum of the number of blows required to drive the sampler over the depth interval of 6 to 18 in. (150 to 450 mm) (see 7.3).

3.1.9 ΔN —the number of blows obtained from each of the 6-in. (150-mm) intervals of sampler penetration (see 7.3).

3.1.10 *number of rope turns*—the total contact angle between the rope and the cathead at the beginning of the operator's rope slackening to drop the hammer, divided by 360° (see Fig. 1).

3.1.11 *sampling rods*—rods that connect the drive-weight assembly to the sampler. Drill rods are often used for this purpose.

3.1.12 *SPT*—abbreviation for standard penetration test, a term by which engineers commonly refer to this method.

4. Significance and Use

4.1 This test method provides a soil sample for identification purposes and for laboratory tests appropriate for soil obtained from a sampler that may produce large shear strain disturbance in the sample.

4.2 This test method is used extensively in a great variety of geotechnical exploration projects. Many local correlations and

¹ This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

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² Annual Book of ASTM Standards, Vol 04.08.

³ Annual Book of ASTM Standards, Vol 04.09.

*A Summary of Changes section appears at the end of this standard.

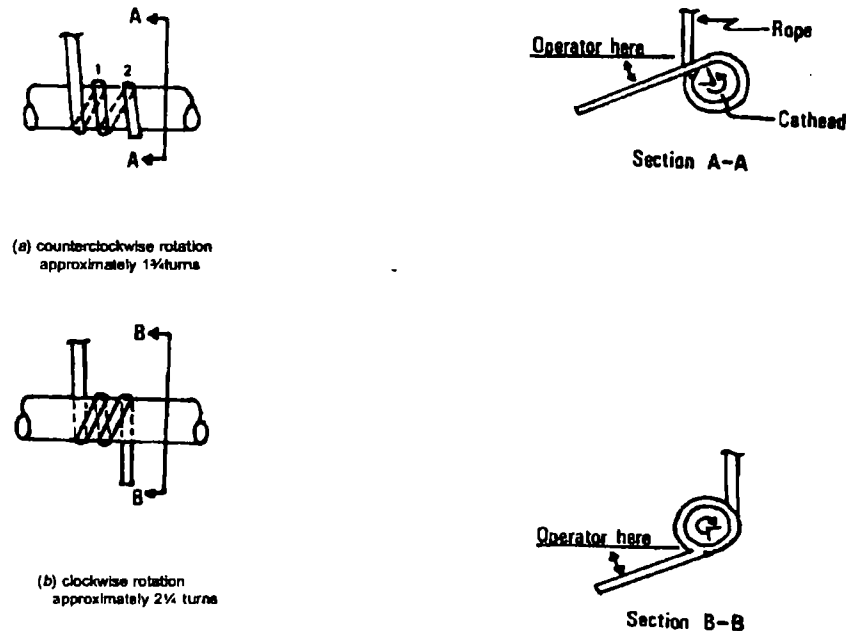


FIG. 1 Definitions of the Number of Rope Turns and the Angle for (a) Counterclockwise Rotation and (b) Clockwise Rotation of the Cathode

widely published correlations which relate SPT blowcount, or *N*-value, and the engineering behavior of earthworks and foundations are available.

5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment that provides at the time of sampling a suitably clean open hole before insertion of the sampler and ensures that the penetration test is performed on undisturbed soil shall be acceptable. The following pieces of equipment have proven to be suitable for advancing a borehole in some subsurface conditions.

5.1.1 *Drag, Chopping, and Fishtail Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods. To avoid disturbance of the underlying soil, bottom discharge bits are not permitted; only side discharge bits are permitted.

5.1.2 *Roller-Cone Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods if the drilling fluid discharge is deflected.

5.1.3 *Hollow-Stem Continuous Flight Augers*, with or without a center bit assembly, may be used to drill the boring. The inside diameter of the hollow-stem augers shall be less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm).

5.1.4 *Solid, Continuous Flight, Bucket and Hand Augers*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in

diameter may be used if the soil on the side of the boring does not cave onto the sampler or sampling rods during sampling.

5.2 *Sampling Rods*—Flush-joint steel drill rods shall be used to connect the split-barrel sampler to the drive-weight assembly. The sampling rod shall have a stiffness (moment of inertia) equal to or greater than that of parallel wall "A" rod (a steel rod which has an outside diameter of 1 1/2 in. (41.2 mm) and an inside diameter of 1 1/8 in. (28.5 mm)).

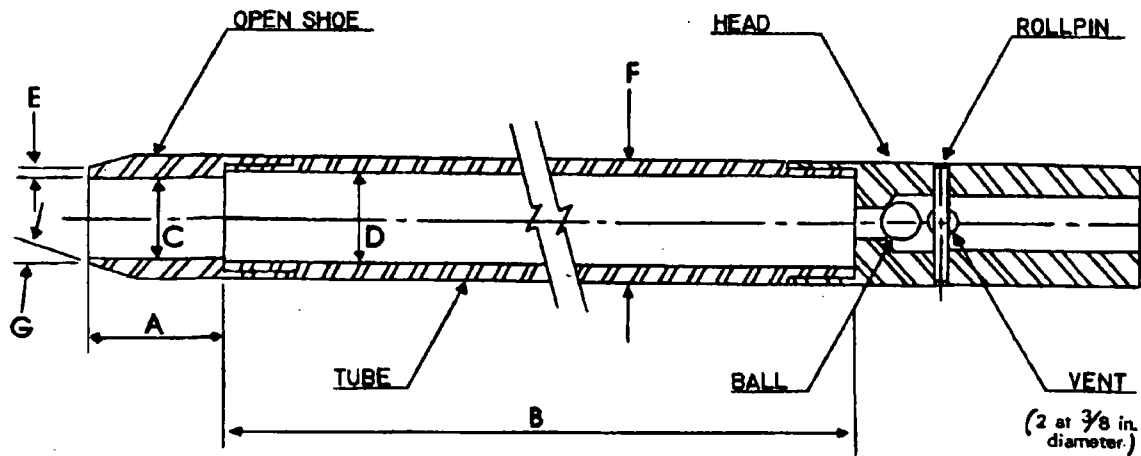
NOTE 2—Recent research and comparative testing indicates the type rod used, with stiffness ranging from "A" size rod to "N" size rod, will usually have a negligible effect on the *N*-values to depths of at least 100 ft (30 m).

5.3 *Split-Barrel Sampler*—The sampler shall be constructed with the dimensions indicated in Fig. 2. The driving shoe shall be of hardened steel and shall be replaced or repaired when it becomes dented or distorted. The use of liners to produce a constant inside diameter of 1 3/8 in. (35 mm) is permitted, but shall be noted on the penetration record if used. The use of a sample retainer basket is permitted, and should also be noted on the penetration record if used.

NOTE 3—Both theory and available test data suggest that *N*-values may increase between 10 to 30 % when liners are used.

5.4 Drive-Weight Assembly:

5.4.1 *Hammer and Anvil*—The hammer shall weigh 140 ± 2 lb (63.5 ± 1 kg) and shall be a solid rigid metallic mass. The hammer shall strike the anvil and make steel on steel contact when it is dropped. A hammer fall guide permitting a free fall



- A = 1.0 to 2.0 in. (25 to 50 mm)
 B = 18.0 to 30.0 in. (0.457 to 0.762 m)
 C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
 D = 1.50 ± 0.05 - 0.00 in. (38.1 ± 1.3 - 0.0 mm)
 E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
 F = 2.00 ± 0.05 - 0.00 in. (50.8 ± 1.3 - 0.0 mm)
 G = 16.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

FIG. 2 Split-Barrel Sampler

shall be used. Hammers used with the cathead and rope method shall have an unimpeded overlift capacity of at least 4 in. (100 mm). For safety reasons, the use of a hammer assembly with an internal anvil is encouraged.

NOTE 4—It is suggested that the hammer fall guide be permanently marked to enable the operator or inspector to judge the hammer drop height.

5.4.2 *Hammer Drop System*—Rope-cathead, trip, semi-automatic, or automatic hammer drop systems may be used, providing the lifting apparatus will not cause penetration of the sampler while re-engaging and lifting the hammer.

5.5 *Accessory Equipment*—Accessories such as labels, sample containers, data sheets, and groundwater level measuring devices shall be provided in accordance with the requirements of the project and other ASTM standards.

6. Drilling Procedure

6.1 The boring shall be advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the project engineer or geologist. Typically, the intervals selected are 5 ft (1.5 m) or less in homogeneous strata with test and sampling locations at every change of strata.

6.2 Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test is performed on essentially undisturbed soil shall be acceptable. Each of the following procedures have proven to be acceptable for some subsurface conditions. The subsurface conditions anticipated should be considered when selecting the drilling method to be used.

6.2.1 Open-hole rotary drilling method.

6.2.2 Continuous flight hollow-stem auger method.

6.2.3 Wash boring method.

6.2.4 Continuous flight solid auger method.

6.3 Several drilling methods produce unacceptable borings.

The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. The continuous flight solid auger method shall not be used for advancing the boring below a water table or below the upper confining bed of a confined non-cohesive stratum that is under artesian pressure. Casing may not be advanced below the sampling elevation prior to sampling. Advancing a boring with bottom discharge bits is not permissible. It is not permissible to advance the boring for subsequent insertion of the sampler solely by means of previous sampling with the SPT sampler.

6.4 The drilling fluid level within the boring or hollow-stem augers shall be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling.

7. Sampling and Testing Procedure

7.1 After the boring has been advanced to the desired sampling elevation and excessive cuttings have been removed, prepare for the test with the following sequence of operations.

7.1.1 Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.

7.1.2 Position the hammer above and attach the anvil to the top of the sampling rods. This may be done before the sampling

rods and sampler are lowered into the borehole.

7.1.3 Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings are encountered at the bottom of the boring, remove the sampler and sampling rods from the boring and remove the cuttings.

7.1.4 Mark the drill rods in three successive 6-in. (0.15-m) increments so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-in. (0.15-m) increment.

7.2 Drive the sampler with blows from the 140-lb (63.5-kg) hammer and count the number of blows applied in each 6-in. (0.15-m) increment until one of the following occurs:

7.2.1 A total of 50 blows have been applied during any one of the three 6-in. (0.15-m) increments described in 7.1.4.

7.2.2 A total of 100 blows have been applied.

7.2.3 There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

7.2.4 The sampler is advanced the complete 18 in. (0.45 m) without the limiting blow counts occurring as described in 7.2.1, 7.2.2, or 7.2.3.

7.3 Record the number of blows required to effect each 6 in. (0.15 m) of penetration or fraction thereof. The first 6 in. is considered to be a seating drive. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance," or the "*N*-value." If the sampler is driven less than 18 in. (0.45 m), as permitted in 7.2.1, 7.2.2, or 7.2.3, the number of blows per each complete 6-in. (0.15-m) increment and per each partial increment shall be recorded on the boring log. For partial increments, the depth of penetration shall be reported to the nearest 1 in. (25 mm), in addition to the number of blows. If the sampler advances below the bottom of the boring under the static weight of the drill rods or the weight of the drill rods plus the static weight of the hammer, this information should be noted on the boring log.

7.4 The raising and dropping of the 140-lb (63.5-kg) hammer shall be accomplished using either of the following two methods:

7.4.1 By using a trip, automatic, or semi-automatic hammer drop system which lifts the 140-lb (63.5-kg) hammer and allows it to drop 30 ± 1.0 in. (0.76 m \pm 25 mm) unimpeded.

7.4.2 By using a cathead to pull a rope attached to the hammer. When the cathead and rope method is used the system and operation shall conform to the following:

7.4.2.1 The cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 in. (150 to 250 mm).

7.4.2.2 The cathead should be operated at a minimum speed of rotation of 100 RPM, or the approximate speed of rotation shall be reported on the boring log.

7.4.2.3 No more than 2¼ rope turns on the cathead may be used during the performance of the penetration test, as shown in Fig. 1.

NOTE 5—The operator should generally use either 1¼ or 2¼ rope turns, depending upon whether or not the rope comes off the top (1¼ turns) or the bottom (2¼ turns) of the cathead. It is generally known and accepted that 2¼ or more rope turns considerably impedes the fall of the hammer and should not be used to perform the test. The cathead rope should be maintained in a relatively dry, clean, and unfayed condition.

7.4.2.4 For each hammer blow, a 30-in. (0.76-m) lift and drop shall be employed by the operator. The operation of pulling and throwing the rope shall be performed rhythmically without holding the rope at the top of the stroke.

7.5 Bring the sampler to the surface and open. Record the percent recovery or the length of sample recovered. Describe the soil samples recovered as to composition, color, stratification, and condition, then place one or more representative portions of the sample into sealable moisture-proof containers (jars) without ramming or distorting any apparent stratification. Seal each container to prevent evaporation of soil moisture. Affix labels to the containers bearing job designation, boring number, sample depth, and the blow count per 6-in. (0.15-m) increment. Protect the samples against extreme temperature changes. If there is a soil change within the sampler, make a jar for each stratum and note its location in the sampler barrel.

8. Report

8.1 Drilling information shall be recorded in the field and shall include the following:

- 8.1.1 Name and location of job,
- 8.1.2 Names of crew,
- 8.1.3 Type and make of drilling machine,
- 8.1.4 Weather conditions,
- 8.1.5 Date and time of start and finish of boring,
- 8.1.6 Boring number and location (station and coordinates, if available and applicable),
- 8.1.7 Surface elevation, if available,
- 8.1.8 Method of advancing and cleaning the boring,
- 8.1.9 Method of keeping boring open,
- 8.1.10 Depth of water surface and drilling depth at the time of a noted loss of drilling fluid, and time and date when reading or notation was made,
- 8.1.11 Location of strata changes,
- 8.1.12 Size of casing, depth of cased portion of boring,
- 8.1.13 Equipment and method of driving sampler,
- 8.1.14 Type sampler and length and inside diameter of barrel (note use of liners),
- 8.1.15 Size, type, and section length of the sampling rods, and
- 8.1.16 Remarks.

8.2 Data obtained for each sample shall be recorded in the field and shall include the following:

- 8.2.1 Sample depth and, if utilized, the sample number,
- 8.2.2 Description of soil,
- 8.2.3 Strata changes within sample,
- 8.2.4 Sampler penetration and recovery lengths, and
- 8.2.5 Number of blows per 6-in. (0.15-m) or partial increment.

9. Precision and Bias

9.1 *Precision*—A valid estimate of test precision has not been determined because it is too costly to conduct the necessary inter-laboratory (field) tests. Subcommittee D18.02 welcomes proposals to allow development of a valid precision statement.

9.2 *Bias*—Because there is no reference material for this test method, there can be no bias statement.

9.3 Variations in *N*-values of 100 % or more have been

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observed when using different standard penetration test apparatus and drillers for adjacent borings in the same soil formation. Current opinion, based on field experience, indicates that when using the same apparatus and driller, N -values in the same soil can be reproduced with a coefficient of variation of about 10 %.

9.4 The use of faulty equipment, such as an extremely massive or damaged anvil, a rusty cathead, a low speed cathead, an old, oily rope, or massive or poorly lubricated rope sheaves can significantly contribute to differences in N -values obtained between operator-drill rig systems.

9.5 The variability in N -values produced by different drill rigs and operators may be reduced by measuring that part of the hammer energy delivered into the drill rods from the sampler and adjusting N on the basis of comparative energies. A method for energy measurement and N -value adjustment is given in Test Method D 4633.

10. Keywords

10.1 blow count; in-situ test; penetration resistance; split-barrel sampling; standard penetration test

SUMMARY OF CHANGES

(1) Added note to Section 1, Scope. The note refers to a related standard, Practice D 6066.

(2) Added Practice D 6066 to Section 2 on Referenced Documents.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

ASTM METHOD D 2488-93

STANDARD PRACTICE FOR
DESCRIPTION AND IDENTIFICATION OF SOILS
(VISUAL-MANUAL PROCEDURE)

20443

APPI



Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)¹

This standard is issued under the fixed designation D 2488; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This practice covers procedures for the description of soils for engineering purposes.

1.2 This practice also describes a procedure for identifying soils, at the option of the user, based on the classification system described in Test Method D 2487. The identification is based on visual examination and manual tests. It must be clearly stated in reporting an identification that it is based on visual-manual procedures.

1.2.1 When precise classification of soils for engineering purposes is required, the procedures prescribed in Test Method D 2487 shall be used.

1.2.2 In this practice, the identification portion assigning a group symbol and name is limited to soil particles smaller than 3 in. (75 mm).

1.2.3 The identification portion of this practice is limited to naturally occurring soils (disturbed and undisturbed).

NOTE 1—This practice may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. (See Appendix X2).

1.3 The descriptive information in this practice may be used with other soil classification systems or for materials other than naturally occurring soils.

1.4 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. For specific precautionary statements see Section 8.*

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:

D 653 Terminology Relating to Soil, Rock, and Contained Fluids²

D 1452 Practice for Soil Investigation and Sampling by Auger Borings²

D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils²

D 1587 Practice for Thin-Walled Tube Sampling of Soils²

D 2113 Practice for Diamond Core Drilling for Site Investigation²

D 2487 Classification of Soils for Engineering Purposes (Unified Soil Classification System)²

D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)²

3. Terminology

3.1 Definitions:

3.1.1 Except as listed below, all definitions are in accordance with Terminology D 653.

NOTE 2—For particles retained on a 3-in. (75-mm) US standard sieve, the following definitions are suggested:

Cobbles—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) sieve, and

Boulders—particles of rock that will not pass a 12-in. (300-mm) square opening.

3.1.1.2 **clay**—soil passing a No. 200 (75- μ m) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the "A" line (see Fig. 3 of Test Method D 2487).

3.1.1.3 **gravel**—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions:

coarse—passes a 3-in. (75-mm) sieve and is retained on a 3/4-in. (19-mm) sieve.

fine—passes a 3/4-in. (19-mm) sieve and is retained on a No. 4 (4.75-mm) sieve.

3.1.1.4 **organic clay**—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay, except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.1.5 **organic silt**—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.1.6 **peat**—a soil composed primarily of vegetable tissue in various stages of decomposition usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.1.1.7 **sand**—particles of rock that will pass a No. 4

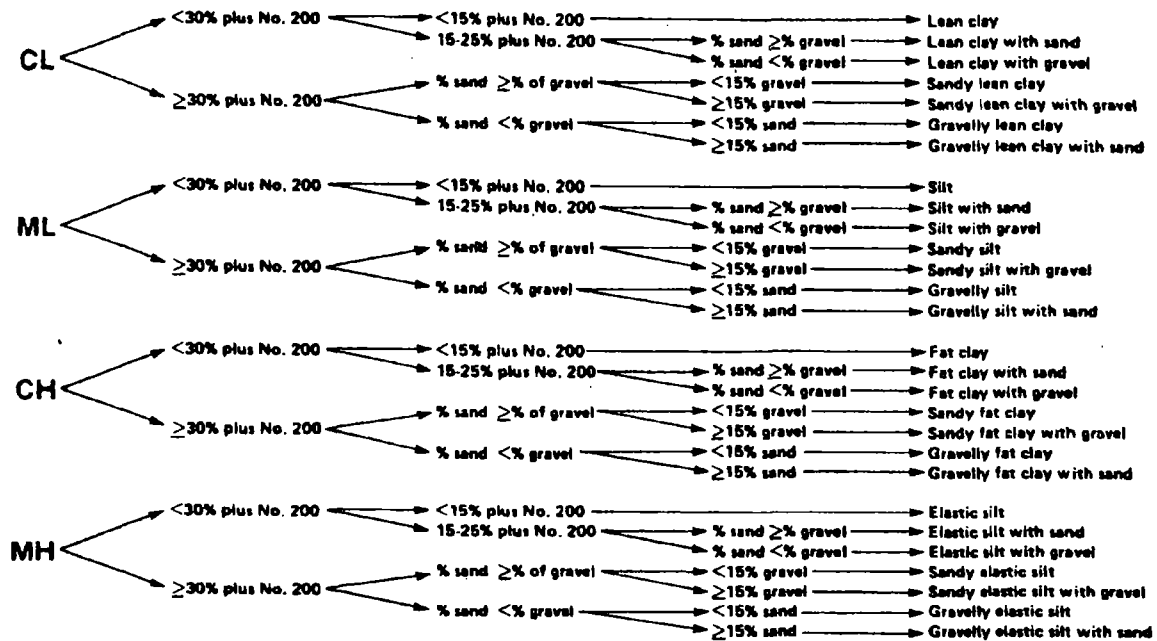
¹ This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

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² Annual Book of ASTM Standards, Vol 04.08.

GROUP SYMBOL

GROUP NAME



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1a Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)

(4.75-mm) sieve and be retained on a No. 200 (75-μm) sieve with the following subdivisions:

coarse—passes a No. 4 (4.75-mm) sieve and is retained on a No. 10 (2.00-mm) sieve.

medium—passes a No. 10 (2.00-mm) sieve and is retained on a No. 40 (425-μm) sieve.

fine—passes a No. 40 (425-μm) sieve and is retained on a No. 200 (75-μm) sieve.

3.1.1.8 *silt*—soil passing a No. 200 (75-μm) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4, or the plot of plasticity index versus liquid limit falls below the “A” line (see Fig. 3 of Test Method D 2487).

4. Summary of Practice

4.1 Using visual examination and simple manual tests, this practice gives standardized criteria and procedures for describing and identifying soils.

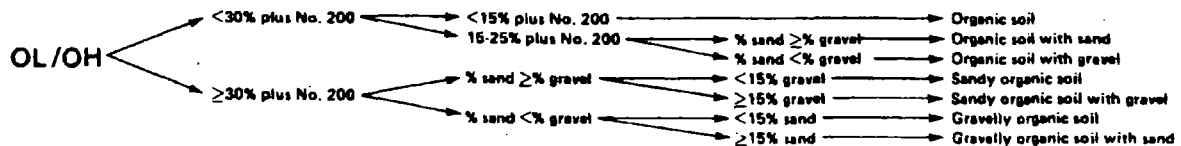
4.2 The soil can be given an identification by assigning a group symbol(s) and name. The flow charts, Figs. 1a and 1b for fine-grained soils, and Fig. 2, for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name. If the soil has properties which do not distinctly place it into a specific group, borderline symbols may be used, see Appendix X3.

NOTE 3—It is suggested that a distinction be made between *dual symbols* and *borderline symbols*.

Dual Symbol—A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC, CL-ML used to indicate that the soil has been identified as having the properties of a classification in accordance with Test Method D 2487 where two symbols are required. Two symbols are required when the soil has between 5 and 12 % fines or

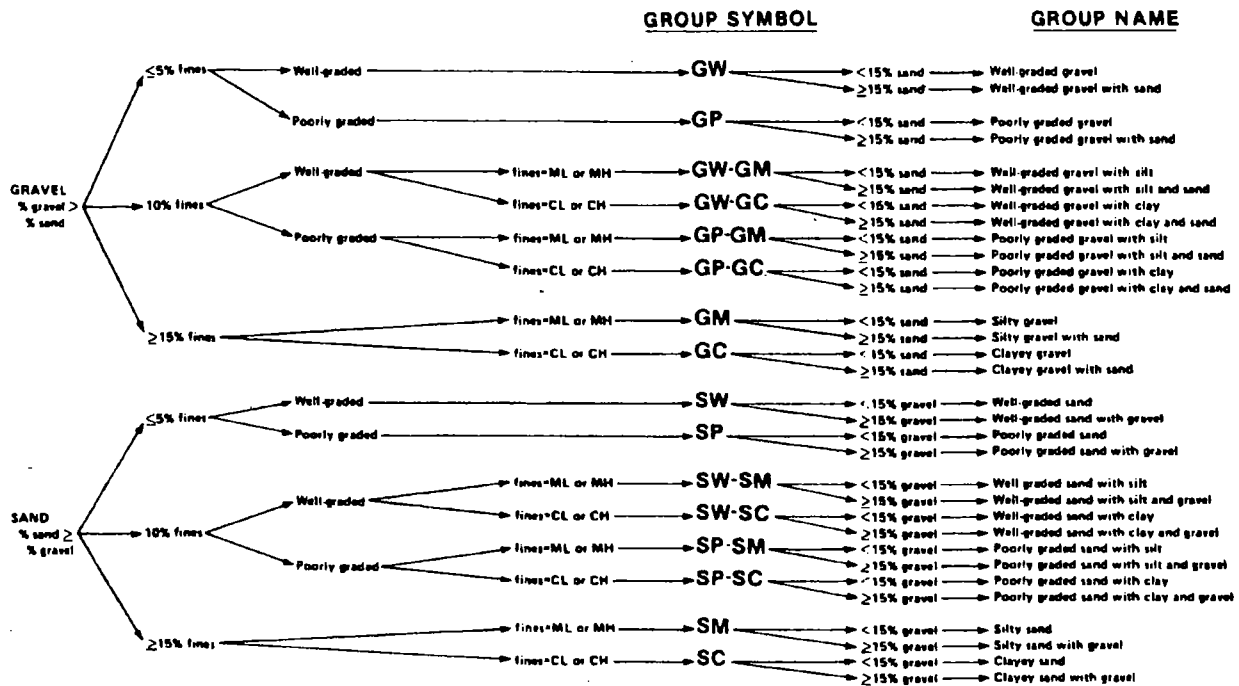
GROUP SYMBOL

GROUP NAME



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1b Flow Chart for Identifying Organic Fine-Grained Soil (50 % or more fines)



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 2 Flow Chart for Identifying Coarse-Grained Soils (less than 50 % fines)

when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

Borderline Symbol—A borderline symbol is two symbols separated by a slash, for example, CL/CH, GM/SM, CL/ML. A borderline symbol should be used to indicate that the soil has been identified as having properties that do not distinctly place the soil into a specific group (see Appendix X3).

5. Significance and Use

5.1 The descriptive information required in this practice can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.2 The descriptive information required in this practice should be used to supplement the classification of a soil as determined by Test Method D 2487.

5.3 This practice may be used in identifying soils using the classification group symbols and names as prescribed in Test Method D 2487. Since the names and symbols used in this practice to identify the soils are the same as those used in Test Method D 2487, it shall be clearly stated in reports and all other appropriate documents, that the classification symbol and name are based on visual-manual procedures.

5.4 This practice is to be used not only for identification of soils in the field, but also in the office, laboratory, or wherever soil samples are inspected and described.

5.5 This practice has particular value in grouping similar soil samples so that only a minimum number of laboratory tests need be run for positive soil classification.

NOTE 4—The ability to describe and identify soils correctly is learned more readily under the guidance of experienced personnel, but it may also be acquired systematically by comparing numerical laboratory test

results for typical soils of each type with their visual and manual characteristics.

5.6 When describing and identifying soil samples from a given boring, test pit, or group of borings or pits, it is not necessary to follow all of the procedures in this practice for every sample. Soils which appear to be similar can be grouped together; one sample completely described and identified with the others referred to as similar based on performing only a few of the descriptive and identification procedures described in this practice.

5.7 This practice may be used in combination with Practice D 4083 when working with frozen soils.

6. Apparatus

6.1 Required Apparatus:

6.1.1 Pocket Knife or Small Spatula.

6.2 Useful Auxiliary Apparatus:

6.2.1 Small Test Tube and Stopper (or jar with a lid).

6.2.2 Small Hand Lens

7. Reagents

7.1 Purity of Water—Unless otherwise indicated, references to water shall be understood to mean water from a city water supply or natural source, including non-potable water.

7.2 Hydrochloric Acid—A small bottle of dilute hydrochloric acid, HCl, one part HCl (10 N) to three parts water (This reagent is optional for use with this practice). See Section 8.

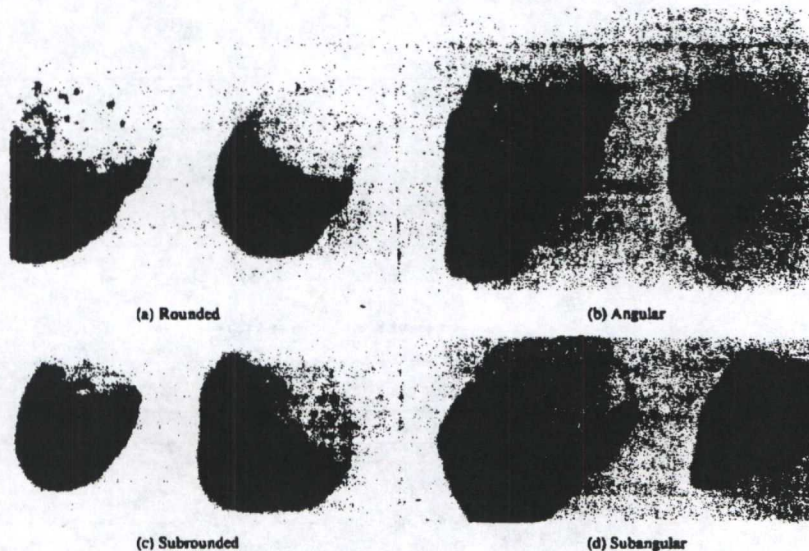


FIG. 3 Typical Angularity of Bulky Grains

8. Safety Precautions

8.1 When preparing the dilute HCl solution of one part concentrated hydrochloric acid (10 N) to three parts of distilled water, slowly add acid into water following necessary safety precautions. Handle with caution and store safely. If solution comes into contact with the skin, rinse thoroughly with water.

8.2 Caution—Do not add water to acid.

9. Sampling

9.1 The sample shall be considered to be representative of the stratum from which it was obtained by an appropriate, accepted, or standard procedure.

NOTE 5—Preferably, the sampling procedure should be identified as having been conducted in accordance with Practices D 1452, D 1587, or D 2113, or Method D 1586.

9.2 The sample shall be carefully identified as to origin.

NOTE 6—Remarks as to the origin may take the form of a boring number and sample number in conjunction with a job number, a geologic stratum, a pedologic horizon or a location description with respect to a permanent monument, a grid system or a station number and offset with respect to a stated centerline and a depth or elevation.

9.3 For accurate description and identification, the minimum amount of the specimen to be examined shall be in

TABLE 1 Criteria for Describing Angularity of Coarse-Grained Particles (see Fig. 3)

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular description but have rounded edges
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

accordance with the following schedule:

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (¾ in.)	200 g (0.5 lb)
19.0 mm (¾ in.)	1.0 kg (2.2 lb)
38.1 mm (1½ in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

NOTE 7—If random isolated particles are encountered that are significantly larger than the particles in the soil matrix, the soil matrix can be accurately described and identified in accordance with the preceding schedule.

9.4 If the field sample or specimen being examined is smaller than the minimum recommended amount, the report shall include an appropriate remark.

10. Descriptive Information for Soils

10.1 *Angularity*—Describe the angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, as angular, subangular, subrounded, or rounded in accordance with the criteria in Table 1 and Fig. 3. A range of angularity may be stated, such as: subrounded to rounded.

10.2 *Shape*—Describe the shape of the gravel, cobbles, and boulders as flat, elongated, or flat and elongated if they meet the criteria in Table 2 and Fig. 4. Otherwise, do not mention the shape. Indicate the fraction of the particles that have the shape, such as: one-third of the gravel particles are flat.

10.3 *Color*—Describe the color. Color is an important property in identifying organic soils, and within a given

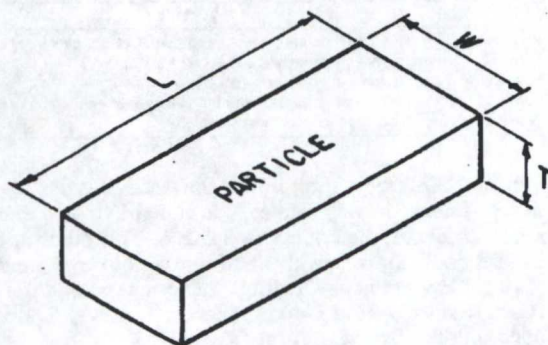
TABLE 2 Criteria for Describing Particle Shape (see Fig. 4)

The particle shape shall be described as follows where length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively.

Flat	Particles with width/thickness > 3
Elongated	Particles with length/width > 3
Flat and elongated	Particles meet criteria for both flat and elongated

PARTICLE SHAPE

W = WIDTH
T = THICKNESS
L = LENGTH



FLAT: $W/T > 3$
ELONGATED: $L/W > 3$
FLAT AND ELONGATED:
- meets both criteria

FIG. 4 Criteria for Particle Shape

TABLE 3 Criteria for Describing Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

locality it may also be useful in identifying materials of similar geologic origin. If the sample contains layers or patches of varying colors, this shall be noted and all representative colors shall be described. The color shall be described for moist samples. If the color represents a dry condition, this shall be stated in the report.

10.4 *Odor*—Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. This is especially apparent in fresh samples, but if the samples are dried, the odor may often be revived by heating a moistened sample. If the odor is unusual (petroleum product, chemical, and the like), it shall be described.

10.5 *Moisture Condition*—Describe the moisture condition as dry, moist, or wet, in accordance with the criteria in Table 3.

10.6 *HCl Reaction*—Describe the reaction with HCl as none, weak, or strong, in accordance with the criteria in Table 4. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important.

TABLE 4 Criteria for Describing the Reaction With HCl

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

TABLE 5 Criteria for Describing Consistency

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about 1/4 in. (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

10.7 *Consistency*—For intact fine-grained soil, describe the consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria in Table 5. This observation is inappropriate for soils with significant amounts of gravel.

10.8 *Cementation*—Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the criteria in Table 6.

10.9 *Structure*—Describe the structure of intact soils in accordance with the criteria in Table 7.

10.10 *Range of Particle Sizes*—For gravel and sand components, describe the range of particle sizes within each component as defined in 3.1.2 and 3.1.6. For example, about 20 % fine to coarse gravel, about 40 % fine to coarse sand.

10.11 *Maximum Particle Size*—Describe the maximum particle size found in the sample in accordance with the following information:

10.11.1 *Sand Size*—If the maximum particle size is a sand size, describe as fine, medium, or coarse as defined in 3.1.6. For example: maximum particle size, medium sand.

10.11.2 *Gravel Size*—If the maximum particle size is a gravel size, describe the maximum particle size as the smallest sieve opening that the particle will pass. For example, maximum particle size, 1 1/2 in. (will pass a 1 1/2-in. square opening but not a 3/4-in. square opening).

10.11.3 *Cobble or Boulder Size*—If the maximum particle size is a cobble or boulder size, describe the maximum dimension of the largest particle. For example: maximum dimension, 18 in. (450 mm).

10.12 *Hardness*—Describe the hardness of coarse sand and larger particles as hard, or state what happens when the particles are hit by a hammer, for example, gravel-size particles fracture with considerable hammer blow, some gravel-size particles crumble with hammer blow. "Hard" means particles do not crack, fracture, or crumble under a hammer blow.

10.13 Additional comments shall be noted, such as the presence of roots or root holes, difficulty in drilling or augering hole, caving of trench or hole, or the presence of mica.

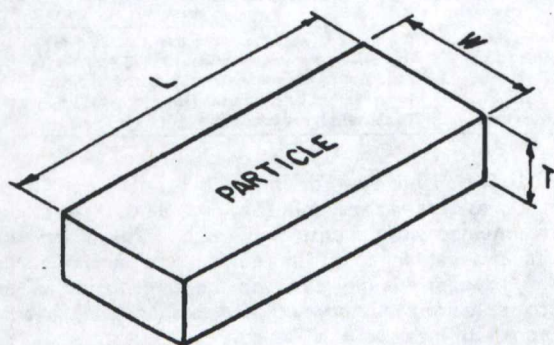
10.14 A local or commercial name or a geologic interpretation.

TABLE 6 Criteria for Describing Cementation

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

PARTICLE SHAPE

W = WIDTH
T = THICKNESS
L = LENGTH



FLAT: $W/T > 3$
ELONGATED: $L/W > 3$
FLAT AND ELONGATED:
—meets both criteria

FIG. 4 Criteria for Particle Shape

TABLE 3 Criteria for Describing Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

locality it may also be useful in identifying materials of similar geologic origin. If the sample contains layers or patches of varying colors, this shall be noted and all representative colors shall be described. The color shall be described for moist samples. If the color represents a dry condition, this shall be stated in the report.

10.4 *Odor*—Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. This is especially apparent in fresh samples, but if the samples are dried, the odor may often be revived by heating a moistened sample. If the odor is unusual (petroleum product, chemical, and the like), it shall be described.

10.5 *Moisture Condition*—Describe the moisture condition as dry, moist, or wet, in accordance with the criteria in Table 3.

10.6 *HCl Reaction*—Describe the reaction with HCl as none, weak, or strong, in accordance with the criteria in Table 4. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important.

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Description	Criteria
None	No visible reaction
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Strong	Violent reaction, with bubbles forming immediately

TABLE 5 Criteria for Describing Consistency

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about 1/4 in. (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

10.7 *Consistency*—For intact fine-grained soil, describe the consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria in Table 5. This observation is inappropriate for soils with significant amounts of gravel.

10.8 *Cementation*—Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the criteria in Table 6.

10.9 *Structure*—Describe the structure of intact soils in accordance with the criteria in Table 7.

10.10 *Range of Particle Sizes*—For gravel and sand components, describe the range of particle sizes within each component as defined in 3.1.2 and 3.1.6. For example, about 20 % fine to coarse gravel, about 40 % fine to coarse sand.

10.11 *Maximum Particle Size*—Describe the maximum particle size found in the sample in accordance with the following information:

10.11.1 *Sand Size*—If the maximum particle size is a sand size, describe as fine, medium, or coarse as defined in 3.1.6. For example: maximum particle size, medium sand.

10.11.2 *Gravel Size*—If the maximum particle size is a gravel size, describe the maximum particle size as the smallest sieve opening that the particle will pass. For example, maximum particle size, 1 1/2 in. (will pass a 1 1/2-in. square opening but not a 3/4-in. square opening).

10.11.3 *Cobble or Boulder Size*—If the maximum particle size is a cobble or boulder size, describe the maximum dimension of the largest particle. For example: maximum dimension, 18 in. (450 mm).

10.12 *Hardness*—Describe the hardness of coarse sand and larger particles as hard, or state what happens when the particles are hit by a hammer, for example, gravel-size particles fracture with considerable hammer blow, some gravel-size particles crumble with hammer blow. "Hard" means particles do not crack, fracture, or crumble under a hammer blow.

10.13 Additional comments shall be noted, such as the presence of roots or root holes, difficulty in drilling or augering hole, caving of trench or hole, or the presence of mica.

10.14 A local or commercial name or a geologic interpretation

TABLE 6 Criteria for Describing Cementation

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

TABLE 7 Criteria for Describing Structure

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 6 mm thick; note thickness
Laminated	Alternating layers of varying material or color with the layers less than 6 mm thick; note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same color and appearance throughout

tation of the soil, or both, may be added if identified as such.

10.15 A classification or identification of the soil in accordance with other classification systems may be added if identified as such.

11. Identification of Peat

11.1 A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as peat, PT, and not subjected to the identification procedures described hereafter.

12. Preparation for Identification

12.1 The soil identification portion of this practice is based on the portion of the soil sample that will pass a 3-in. (75-mm) sieve. The larger than 3-in. (75-mm) particles must be removed, manually, for a loose sample, or mentally, for an intact sample before classifying the soil.

12.2 Estimate and note the percentage of cobbles and the percentage of boulders. Performed visually, these estimates will be on the basis of volume percentage.

NOTE 8—Since the percentages of the particle-size distribution in Test Method D 2487 are by dry weight, and the estimates of percentages for gravel, sand, and fines in this practice are by dry weight, it is recommended that the report state that the percentages of cobbles and boulders are by volume.

12.3 Of the fraction of the soil smaller than 3 in. (75 mm), estimate and note the percentage, by dry weight, of the gravel, sand, and fines (see Appendix X4 for suggested procedures).

NOTE 9—Since the particle-size components appear visually on the basis of volume, considerable experience is required to estimate the percentages on the basis of dry weight. Frequent comparisons with laboratory particle-size analyses should be made.

12.3.1 The percentages shall be estimated to the closest 5 %. The percentages of gravel, sand, and fines must add up to 100 %.

12.3.2 If one of the components is present but not in sufficient quantity to be considered 5 % of the smaller than 3-in. (75-mm) portion, indicate its presence by the term *trace*, for example, trace of fines. A trace is not to be considered in the total of 100 % for the components.

13. Preliminary Identification

13.1 The soil is *fine grained* if it contains 50 % or more

fines. Follow the procedures for identifying fine-grained soils of Section 14.

13.2 The soil is *coarse grained* if it contains less than 50 % fines. Follow the procedures for identifying coarse-grained soils of Section 15.

14. Procedure for Identifying Fine-Grained Soils

14.1 Select a representative sample of the material for examination. Remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of material is available. Use this specimen for performing the dry strength, dilatancy, and toughness tests.

14.2 Dry Strength:

14.2.1 From the specimen, select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary.

14.2.2 From the molded material, make at least three test specimens. A test specimen shall be a ball of material about 1/2 in. (12 mm) in diameter. Allow the test specimens to dry in air, or sun, or by artificial means, as long as the temperature does not exceed 60°C.

14.2.3 If the test specimen contains natural dry lumps, those that are about 1/2 in. (12 mm) in diameter may be used in place of the molded balls.

NOTE 10—The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.

14.2.4 Test the strength of the dry balls or lumps by crushing between the fingers. Note the strength as none, low, medium, high, or very high in accordance with the criteria in Table 8. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand.

14.2.5 The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrochloric acid (see 10.6).

14.3 Dilatancy:

14.3.1 From the specimen, select enough material to mold into a ball about 1/2 in. (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.

14.3.2 Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on

TABLE 8 Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very high	The dry specimen cannot be broken between the thumb and a hard surface

TABLE 9 Criteria for Describing Dilatancy

Description	Criteria
None	No visible change in the specimen
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing

TABLE 10 Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness

the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria in Table 9. The reaction is the speed with which water appears while shaking, and disappears while squeezing.

14.4 Toughness:

14.4.1 Following the completion of the dilatancy test, the test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about 1/8 in. (3 mm) in diameter. (If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation.) Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about 1/8 in. The thread will crumble at a diameter of 1/8 in. when the soil is near the plastic limit. Note the pressure required to roll the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles. Note the toughness of the material during kneading.

14.4.2 Describe the toughness of the thread and lump as low, medium, or high in accordance with the criteria in Table 10.

14.5 *Plasticity*—On the basis of observations made during the toughness test, describe the plasticity of the material in accordance with the criteria given in Table 11.

14.6 Decide whether the soil is an *inorganic* or an *organic* fine-grained soil (see 14.8). If inorganic, follow the steps given in 14.7.

14.7 Identification of Inorganic Fine-Grained Soils:

TABLE 11 Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A 1/8-in. (3-mm) thread cannot be rolled at any water content
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit

14.7.1 Identify the soil as a *lean clay*, CL, if the soil has medium to high dry strength, no or slow dilatancy, and medium toughness and plasticity (see Table 12).

14.7.2 Identify the soil as a *fat clay*, CH, if the soil has high to very high dry strength, no dilatancy, and high toughness and plasticity (see Table 12).

14.7.3 Identify the soil as a *silt*, ML, if the soil has no to low dry strength, slow to rapid dilatancy, and low toughness and plasticity, or is nonplastic (see Table 12).

14.7.4 Identify the soil as an *elastic silt*, MH, if the soil has low to medium dry strength, no to slow dilatancy, and low to medium toughness and plasticity (see Table 12).

NOTE 11—These properties are similar to those for a lean clay. However, the silt will dry quickly on the hand and have a smooth, silky feel when dry. Some soils that would classify as MH in accordance with the criteria in Test Method D 2487 are visually difficult to distinguish from lean clays, CL. It may be necessary to perform laboratory testing for proper identification.

14.8 Identification of Organic Fine-Grained Soils:

14.8.1 Identify the soil as an *organic soil*, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soils usually have a dark brown to black color and may have an organic odor. Often, organic soils will change color, for example, black to brown, when exposed to the air. Some organic soils will lighten in color significantly when air dried. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

NOTE 12—In some cases, through practice and experience, it may be possible to further identify the organic soils as organic silts or organic clays, OL or OH. Correlations between the dilatancy, dry strength, toughness tests, and laboratory tests can be made to identify organic soils in certain deposits of similar materials of known geologic origin.

14.9 If the soil is estimated to have 15 to 25 % sand or gravel, or both, the words "with sand" or "with gravel" (whichever is more predominant) shall be added to the group name. For example: "lean clay with sand, CL" or "silt with gravel, ML" (see Figs. 1a and 1b). If the percentage of sand is equal to the percentage of gravel, use "with sand."

14.10 If the soil is estimated to have 30 % or more sand or gravel, or both, the words "sandy" or "gravelly" shall be added to the group name. Add the word "sandy" if there appears to be more sand than gravel. Add the word "gravelly" if there appears to be more gravel than sand. For example: "sandy lean clay, CL", "gravelly fat clay, CH", or "sandy silt, ML" (see Figs. 1a and 1b). If the percentage of sand is equal to the percent of gravel, use "sandy."

15. Procedure for Identifying Coarse-Grained Soils (Contains less than 50 % fines)

15.1 The soil is a *gravel* if the percentage of gravel is estimated to be more than the percentage of sand.

TABLE 12 Identification of Inorganic Fine-Grained Soils from Manual Tests

Soil Symbol	Dry Strength	Dilatancy	Toughness
ML	None to low	Slow to rapid	Low or thread cannot be formed
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

15.2 The soil is a *sand* if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

15.3 The soil is a *clean gravel* or *clean sand* if the percentage of fines is estimated to be 5 % or less.

15.3.1 Identify the soil as a *well-graded gravel*, GW, or as a *well-graded sand*, SW, if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes.

15.3.2 Identify the soil as a *poorly graded gravel*, GP, or as a *poorly graded sand*, SP, if it consists predominantly of one size (uniformly graded), or it has a wide range of sizes with some intermediate sizes obviously missing (gap or skip graded).

15.4 The soil is either a *gravel with fines* or a *sand with fines* if the percentage of fines is estimated to be 15 % or more.

15.4.1 Identify the soil as a *clayey gravel*, GC, or a *clayey sand*, SC, if the fines are clayey as determined by the procedures in Section 14.

15.4.2 Identify the soil as a *silty gravel*, GM, or a *silty sand*, SM, if the fines are silty as determined by the procedures in Section 14.

15.5 If the soil is estimated to contain 10 % fines, give the soil a dual identification using two group symbols.

15.5.1 The first group symbol shall correspond to a clean gravel or sand (GW, GP, SW, SP) and the second symbol shall correspond to a gravel or sand with fines (GC, GM, SC, SM).

15.5.2 The group name shall correspond to the first group symbol plus the words "with clay" or "with silt" to indicate the plasticity characteristics of the fines. For example: "well-graded gravel with clay, GW-GC" or "poorly graded sand with silt, SP-SM" (see Fig. 2).

15.6 If the specimen is predominantly sand or gravel but contains an estimated 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example: "poorly graded gravel with sand, GP" or "clayey sand with gravel, SC" (see Fig. 2).

15.7 If the field sample contains any cobbles or boulders, or both; the words "with cobbles" or "with cobbles and boulders" shall be added to the group name. For example: "silty gravel with cobbles, GM."

16. Report

16.1 The report shall include the information as to origin, and the items indicated in Table 13.

NOTE 13—Example: *Clayey Gravel with Sand and Cobbles, GC*—About 50 % fine to coarse, subrounded to subangular gravel; about 30 % fine to coarse, subrounded sand; about 20 % fines with medium plasticity, high dry strength, no dilatancy, medium toughness; weak

TABLE 13 Checklist for Description of Soils

1. Group name
2. Group symbol
3. Percent of cobbles or boulders, or both (by volume)
4. Percent of gravel, sand, or fines, or all three (by dry weight)
5. Particle-size range:
 - Gravel—fine, coarse
 - Sand—fine, medium, coarse
6. Particle angularity: angular, subangular, subrounded, rounded
7. Particle shape: (if appropriate) flat, elongated, flat and elongated
8. Maximum particle size or dimension
9. Hardness of coarse sand and larger particles
10. Plasticity of fines: nonplastic, low, medium, high
11. Dry strength: none, low, medium, high, very high
12. Dilatancy: none, slow, rapid
13. Toughness: low, medium, high
14. Color (in moist condition)
15. Odor (mention only if organic or unusual)
16. Moisture: dry, moist, wet
17. Reaction with HCl: none, weak, strong
- For intact samples:
 - 18. Consistency (fine-grained soils only): very soft, soft, firm, hard, very hard
 - 19. Structure: stratified, laminated, fissured, slickensided, lensed, homogeneous
 - 20. Cementation: weak, moderate, strong
 - 21. Local name
 - 22. Geologic interpretation
 - 23. Additional comments: presence of roots or root holes, presence of mica, gypsum, etc., surface coatings on coarse-grained particles, caving or sloughing of auger hole or trench sides, difficulty in augering or excavating, etc.

reaction with HCl; original field sample had about 5 % (by volume) subrounded cobbles, maximum dimension, 150 mm.

In-Place Conditions—Firm, homogeneous, dry, brown

Geologic Interpretation—Alluvial fan

NOTE 14—Other examples of soil descriptions and identification are given in Appendixes X1 and X2.

NOTE 15—If desired, the percentages of gravel, sand, and fines may be stated in terms indicating a range of percentages, as follows:

Trace—Particles are present but estimated to be less than 5 %

Few—5 to 10 %

Little—15 to 25 %

Some—30 to 45 %

Mostly—50 to 100 %

16.2 If, in the soil description, the soil is identified using a classification group symbol and name as described in Test Method D 2487, it must be distinctly and clearly stated in log forms, summary tables, reports, and the like, that the symbol and name are based on visual-manual procedures.

17. Precision and Bias

17.1 This practice provides qualitative information only, therefore, a precision and bias statement is not applicable.

18. Keywords

18.1 classification; clay; gravel; organic soils; sand; silt; soil classification; soil description; visual classification

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLES OF VISUAL SOIL DESCRIPTIONS

X1.1 The following examples show how the information required in 16.1 can be reported. The information that is included in descriptions should be based on individual circumstances and need.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—About 75 % fine to coarse, hard, subangular gravel; about 25 % fine to coarse, hard, subangular sand; trace of fines; maximum size, 75 mm, brown, dry; no reaction with HCl.

X1.1.2 *Silty Sand with Gravel (SM)*—About 60 % predominantly fine sand; about 25 % silty fines with low plasticity, low dry strength, rapid dilatancy, and low toughness; about 15 % fine, hard, subrounded gravel, a few gravel-size particles fractured with hammer blow; maximum size, 25 mm; no reaction with HCl (Note—Field sample size smaller than recommended).

In-Place Conditions—Firm, stratified and contains lenses of silt 1 to 2 in. (25 to 50 mm) thick, moist, brown to gray;

in-place density 106 lb/ft³; in-place moisture 9 %.

X1.1.3 *Organic Soil (OL/OH)*—About 100 % fines with low plasticity, slow dilatancy, low dry strength, and low toughness; wet, dark brown, organic odor; weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—About 75 % fine to coarse, hard, subangular reddish sand; about 25 % organic and silty dark brown nonplastic fines with no dry strength and slow dilatancy; wet; maximum size, coarse sand; weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—About 75 % fine to coarse, hard, subrounded to subangular gravel; about 15 % fine, hard, subrounded to subangular sand; about 10 % silty nonplastic fines; moist, brown; no reaction with HCl; original field sample had about 5 % (by volume) hard, subrounded cobbles and a trace of hard, subrounded boulders, with a maximum dimension of 18 in. (450 mm).

X2. USING THE IDENTIFICATION PROCEDURE AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, AND THE LIKE

X2.1 The identification procedure may be used as a descriptive system applied to materials that exist in-situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, and the like).

X2.2 Materials such as shells, crushed rock, slag, and the like, should be identified as such. However, the procedures used in this practice for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, an identification using a group name and symbol according to this practice may be assigned to aid in describing the material.

X2.3 The group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how group names and symbols can be incorporated into a descriptive system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. (50 to

100-mm) pieces of shale from power auger hole, dry, brown, no reaction with HCl. After slaking in water for 24 h, material identified as "Sandy Lean Clay (CL)"; about 60 % fines with medium plasticity, high dry strength, no dilatancy, and medium toughness; about 35 % fine to medium, hard sand; about 5 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; "Poorly Graded Sand with Silt (SP-SM)"; about 90 % fine to medium sand; about 10 % nonplastic fines; dry, reddish-brown, strong reaction with HCl.

X2.4.3 *Broken Shells*—About 60 % gravel-size broken shells; about 30 % sand and sand-size shell pieces; about 10 % fines; "Poorly Graded Gravel with Sand (GP)."

X2.4.4 *Crushed Rock*—Processed from gravel and cobbles in Pit No. 7; "Poorly Graded Gravel (GP)"; about 90 % fine, hard, angular gravel-size particles; about 10 % coarse, hard, angular sand-size particles; dry, tan; no reaction with HCl.

X3. SUGGESTED PROCEDURE FOR USING A BORDERLINE SYMBOL FOR SOILS WITH TWO POSSIBLE IDENTIFICATIONS.

X3.1 Since this practice is based on estimates of particle size distribution and plasticity characteristics, it may be difficult to clearly identify the soil as belonging to one category. To indicate that the soil may fall into one of two

possible basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example: SC/CL or CL/CH.

X3.1.1 A borderline symbol may be used when the

percentage of fines is estimated to be between 45 and 55 %. One symbol should be for a coarse-grained soil with fines and the other for a fine-grained soil. For example: GM/ML or CL/SC.

X3.1.2 A borderline symbol may be used when the percentage of sand and the percentage of gravel are estimated to be about the same. For example: GP/SP, SC/GC, GM/SM. It is practically impossible to have a soil that would have a borderline symbol of GW/SW.

X3.1.3 A borderline symbol may be used when the soil could be either well graded or poorly graded. For example: GW/GP, SW/SP.

X3.1.4 A borderline symbol may be used when the soil could either be a silt or a clay. For example: CL/ML, CH/MH, SC/SM.

X3.1.5 A borderline symbol may be used when a fine-

grained soil has properties that indicate that it is at the boundary between a soil of low compressibility and a soil of high compressibility. For example: CL/CH, MH/ML.

X3.2 The order of the borderline symbols should reflect similarity to surrounding or adjacent soils. For example: soils in a borrow area have been identified as CH. One sample is considered to have a borderline symbol of CL and CH. To show similarity, the borderline symbol should be CH/CL.

X3.3 The group name for a soil with a borderline symbol should be the group name for the first symbol, except for:

CL/CH lean to fat clay
ML/CL clayey silt
CL/ML silty clay

X3.4 The use of a borderline symbol should not be used indiscriminately. Every effort shall be made to first place the soil into a single group.

X4. SUGGESTED PROCEDURES FOR ESTIMATING THE PERCENTAGES OF GRAVEL, SAND, AND FINES IN A SOIL SAMPLE

X4.1 *Jar Method*—The relative percentage of coarse- and fine-grained material may be estimated by thoroughly shaking a mixture of soil and water in a test tube or jar, and then allowing the mixture to settle. The coarse particles will fall to the bottom and successively finer particles will be deposited with increasing time; the sand sizes will fall out of suspension in 20 to 30 s. The relative proportions can be estimated from the relative volume of each size separate. This method should be correlated to particle-size laboratory determinations.

X4.2 *Visual Method*—Mentally visualize the gravel size particles placed in a sack (or other container) or sacks. Then, do the same with the sand size particles and the fines. Then, mentally compare the number of sacks to estimate the percentage of plus No. 4 sieve size and minus No. 4 sieve size

present. The percentages of sand and fines in the minus sieve size No. 4 material can then be estimated from the wash test (X4.3).

X4.3 *Wash Test (for relative percentages of sand and fines)*—Select and moisten enough minus No. 4 sieve size material to form a 1-in (25-mm) cube of soil. Cut the cube in half, set one-half to the side, and place the other half in a small dish. Wash and decant the fines out of the material in the dish until the wash water is clear and then compare the two samples and estimate the percentage of sand and fines. Remember that the percentage is based on weight, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

X4.3.1 While washing, it may be necessary to break down lumps of fines with the finger to get the correct percentages.

X5. ABBREVIATED SOIL CLASSIFICATION SYMBOLS

X5.1 In some cases, because of lack of space, an abbreviated system may be useful to indicate the soil classification symbol and name. Examples of such cases would be graphical logs, databases, tables, etc.

X5.2 This abbreviated system is not a substitute for the full name and descriptive information but can be used in supplementary presentations when the complete description is referenced.

X5.3 The abbreviated system should consist of the soil classification symbol based on this standard with appropriate lower case letter prefixes and suffixes as:

<i>Prefix:</i>	<i>Suffix:</i>
s = sandy	s = with sand
g = gravelly	g = with gravel
	c = with cobbles
	b = with boulders

X5.4 The soil classification symbol is to be enclosed in parenthesis. Some examples would be:

<i>Group Symbol and Full Name</i>	<i>Abbreviated</i>
CL, Sandy lean clay	g(CL)
SP-SM, Poorly graded sand with silt and gravel	(SP-SM)g
GP, poorly graded gravel with sand, cobbles, and boulders	(GP)scb
ML, gravelly silt with sand and cobbles	g(ML)sc

X6. RATIONALE

Changes in this version from the previous version, Classification Symbols.
D 2488 - 90, include the addition of X5 on Abbreviated Soil

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Standard Guide for Composite Sampling and Field Subsampling for Environmental Waste Management Activities¹

This standard is issued under the fixed designation D 6051; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

1. Scope

1.1 Compositing and subsampling are key links in the chain of sampling and analytical events that must be performed in compliance with project objectives and instructions to ensure that the resulting data are representative. This guide discusses the advantages and appropriate use of composite sampling, field procedures and techniques to mix the composite sample and procedures to collect an unbiased and precise subsample(s) from a larger sample. It discusses the advantages and limitations of using composite samples in designing sampling plans for characterization of wastes (mainly solid) and potentially contaminated media. This guide assumes that an appropriate sampling device is selected to collect an unbiased sample.

1.2 The guide does not address: where samples should be collected (depends on the objectives) (see Guide D 6044), selection of sampling equipment, bias introduced by selection of inappropriate sampling equipment, sample collection procedures or collection of a representative specimen from a sample, or statistical interpretation of resultant data and devices designed to dynamically sample process waste streams. It also does not provide sufficient information to statistically design an optimized sampling plan, or determine the number of samples to collect or calculate the optimum number of samples to composite to achieve specified data quality objectives (see Practice D 5792). Standard procedures for planning waste sampling activities are addressed in Guide D 4687.

1.3 The sample mixing and subsampling procedures described in this guide are considered inappropriate for samples to be analyzed for volatile organic compounds. Volatile organics are typically lost through volatilization during sample collection, handling, shipping and laboratory sample preparation unless specialized procedures are used. The enhanced mixing described in this guide is expected to cause significant losses of volatile constituents. Specialized procedures should be used for compositing samples for determination of volatiles such as combining directly into methanol (see Practice D 4547).

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- C 702 Practice for Reducing Samples of Aggregate to Testing Size²
- D 1129 Terminology Relating to Water³
- D 4439 Terminology for Geosynthetics⁴
- D 4547 Practice for Sampling Waste and Soils for Volatile Organics⁵
- D 4687 Guide for General Planning of Waste Sampling⁵
- D 5088 Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites⁴
- D 5792 Practice for Generation of Environmental Data Related to Waste Management Activities: Development of Data Quality Objectives⁵
- D 6044 Guide for Representative Sampling for Management of Wastes and Contaminated Media⁵
- E 856 Definitions of Terms and Abbreviations Relating to Physical and Chemical Characteristics of Refuse-Derived Fuel⁵

3. Terminology

3.1 Definitions:

- 3.1.1 *composite sample, n*—a combination of two or more samples. D 1129
- 3.1.2 *sample, n*—a portion of material taken from a larger quantity for the purpose of estimating properties or composition of the larger quantity. E 856
- 3.1.3 *specimen, n*—a specific portion of a material or laboratory sample upon which a test is performed or which is taken for that purpose. D 4439
- 3.1.4 *subsample, n*—a portion of a sample taken for the purpose of estimating properties or composition of the whole sample.
- 3.1.4.1 *Discussion*—a subsample, by definition, is also a sample.

4. Summary of Guide

4.1 This guide describes how the collection of composite samples, as opposed to individual samples, may be used to: more precisely estimate the mean concentration of a waste analyte in contaminated media, reduce costs, efficiently determine the absence or possible presence of a hot spot (a highly contaminated local area), and, when coupled with retesting schemes, efficiently locate hot spots. Specific proce-

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² Annual Book of ASTM Standards, Vol 04.02.

³ Annual Book of ASTM Standards, Vol 11.01.

⁴ Annual Book of ASTM Standards, Vol 04.09.

⁵ Annual Book of ASTM Standards, Vol 11.04.

dures for mixing a sample(s) and collecting subsamples for transport to a laboratory are provided.

5. Significance and Use

5.1 This guide provides guidance to persons managing or responsible for designing sampling and analytical plans for determining whether sample compositing may assist in more efficiently meeting study objectives. Samples must be composited properly, or useful information on contamination distribution and sample variance may be lost.

5.2 The procedures described for mixing samples and obtaining a representative subsample are broadly applicable to waste sampling where it is desired to transport a reduced amount of material to the laboratory. The mixing and subsampling sections provide guidance to persons preparing sampling and analytical plans and field personnel.

5.3 While this guide generally focuses on solid materials, the attributes and limitations of composite sampling apply equally to static liquid samples.

6. Attributes of Composite Sampling for Waste Characterization

6.1 In general, the individual samples to be composited should be of the same mass, however, proportional sampling may be appropriate in some cases depending upon the objective. For example, if the objective is to determine the average drum concentration of a contaminant, compositing equals volumes of waste from each drum would be appropriate. If the objective is to determine average contaminant concentration of the waste contained in a group of drums, the volume of each sample to be composited should be proportional to the amount of waste in each drum. Another example of proportional sampling is estimating the contaminant concentration of soil overlying an impermeable zone. Soil cores should be collected from the surface to the impermeable layer, regardless of core length.

6.2 The principal advantages of sample compositing include: reduction in the variance of an estimated average concentration (1),⁶ increasing the efficiency of locating/identifying hot spots (2), and reduction of sampling and analytical costs (3). These main advantages are discussed in the following paragraphs. However, a principle assumption needed to justify compositing is that analytical costs are high relative to sampling costs. In general, appropriate use of sample compositing can:

6.2.1 reduce inter-sample variance, that is, improve the precision of the mean estimation while reducing the probability of making an incorrect decision,

6.2.2 reduce costs for estimating a total or mean value, especially where analytical costs greatly exceed sampling costs (also may be effective when analytical capacity is a limitation),

6.2.3 efficiently determine the absence or possible presence of hot spots or hot containers and, when combined with retesting schemes, identify hot spots, as long as the probability of hitting a hot spot is low,

6.2.4 be especially useful for situations, where the nature

of contaminant distribution tends to be contiguous and non-random and the majority of analyses are "non-detects" for the contaminant(s) of interest, and

6.2.5 provide a degree of anonymity where population, rather than individual statistics are needed.

6.3 *Improvement in Sampling Precision*—Samples are always taken to make inferences to a larger volume of material, and a set of composite samples from a heterogeneous population provides a more precise estimate of the mean than a comparable number of discrete samples. This occurs because compositing is a "physical process of averaging." Averages of samples have greater precision than the individual samples. Likewise, a set of composite samples is always more precise than an equal number of individual samples. Decisions based on a set of composite samples will, for practical purposes, always provide greater statistical confidence than for a comparable set of individual samples.

6.3.1 If an estimated precision of a mean is desired, then more than one composite sample is needed; a standard deviation cannot be calculated from one composite sample. However, the precision of a single composite sample may be estimated when there are data to show the relationship between the precision of the individual samples that comprise the composite sample and that of the composite sample. The precision (standard deviation) of the composite sample is approximately the precision of the individual samples divided by the square root of the number of individual samples in the composite.

6.4 *Example 1*—An example of how a single composite sample can be used for decision-making purposes is given here. Assume a regulatory limit of 1 mg/kg and a standard deviation of 0.5 mg/kg for the individual samples. If the concentration of a site is estimated to be around 0.6 mg/kg, how many individual samples should be composited to have relatively high confidence that the true concentration does not exceed the regulatory limit when only one composite sample is used? Assuming the composite is well mixed, then the precision of a composite is a function of the number of samples as follows:

Number of Individual Samples in Composite	Precision (standard deviation $\div \sqrt{n}$) of One Composite Sample
2	0.35
3	0.29
4	0.25
5	0.22
6	0.20

Thus, if six samples are included in a composite, the composite concentration of 0.6 mg/kg is two standard deviations below the regulatory limit. Therefore, if the composite concentration is actually observed to be in the neighborhood of 0.6 mg/kg, we can be reasonably confident (approximately 95 %) that the concentration of the site is below the regulatory limit, using only one composite sample.

6.5 *Example 2*—Another example is when the standard deviation of the individual samples in the previous example is relatively small, say 0.1 mg/kg. Then the standard deviation of a composite of 6 individual samples is 0.04 mg/kg (0.1 mg/kg divided by the square root of 6 = 0.04 mg/kg), a very small number relative to the regulatory limit of 1 mg/kg. In this case, simple comparison of the composite concentration to the regulatory limit is often quite adequate for decision-making purposes.

⁶ The boldface numbers in parentheses refer to a list of references at the end of this guide.

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6.3 *Improvement in Sampling Precision*—Samples are always taken to make inferences to a larger volume of material, and a set of composite samples from a heterogeneous population provides a more precise estimate of the mean than a comparable number of discrete samples. This occurs because compositing is a "physical process of averaging." Averages of samples have greater precision than the individual samples. Likewise, a set of composite samples is always more precise than an equal number of individual samples. Decisions based on a set of composite samples will, for practical purposes, always provide greater statistical confidence than for a comparable set of individual samples.

6.3.1 If an estimated precision of a mean is desired, then more than one composite sample is needed; a standard deviation cannot be calculated from one composite sample. However, the precision of a single composite sample may be estimated when there are data to show the relationship between the precision of the individual samples that comprise the composite sample and that of the composite sample. The precision (standard deviation) of the composite sample is approximately the precision of the individual samples divided by the square root of the number of individual samples in the composite.

6.4 *Example 1*—An example of how a single composite sample can be used for decision-making purposes is given here. Assume a regulatory limit of 1 mg/kg and a standard deviation of 0.5 mg/kg for the individual samples. If the concentration of a site is estimated to be around 0.6 mg/kg, how many individual samples should be composited to have relatively high confidence that the true concentration does not exceed the regulatory limit when only one composite sample is used? Assuming the composite is well mixed, then the precision of a composite is a function of the number of samples as follows:

Number of Individual Samples in Composite	Precision (standard deviation $\div \sqrt{n}$) of One Composite Sample
2	0.35
3	0.29
4	0.25
5	0.22
6	0.20

Thus, if six samples are included in a composite, the composite concentration of 0.6 mg/kg is two standard deviations below the regulatory limit. Therefore, if the composite concentration is actually observed to be in the neighborhood of 0.6 mg/kg, we can be reasonably confident (approximately 95 %) that the concentration of the site is below the regulatory limit, using only one composite sample.

6.5 *Example 2*—Another example is when the standard deviation of the individual samples in the previous example is relatively small, say 0.1 mg/kg. Then the standard deviation of a composite of 6 individual samples is 0.04 mg/kg (0.1 mg/kg divided by the square root of 6 = 0.04 mg/kg), a very small number relative to the regulatory limit of 1 mg/kg. In this case, simple comparison of the composite concentration to the regulatory limit is often quite adequate for decision-making purposes.

⁶ The boldface numbers in parentheses refer to a list of references at the end of this guide.

6.5.1 The effectiveness of compositing depends on the relative magnitude of sampling and analytical error. When sampling uncertainty is high relative to analytical error (as is usually assumed to be the case) compositing is very effective in improving precision. If analytical errors are high relative to field errors, sample compositing is much less effective.

6.5.2 Because compositing is a physical averaging process, composite samples tend to be more normally distributed than the individual samples. The normalizing effect is frequently an advantage since calculation of means, standard deviations and confidence intervals generally assume the data are normally distributed. Although environmental residue data are commonly non-normally distributed, compositing often leads to approximate normality and avoids the need to transform the data.

6.5.3 The spatial design of the compositing scheme can be important. Depending upon the locations from which the individual samples are collected and composited, composites can be used to determine spatial variability or improve the precision of the parameter being estimated. Figures 1 and 2 represent a site divided into four cells. Composite all samples with the same number together. The sampling approach in Fig. 1 is similar to sample random sampling, except they are now composite samples. Each composite sample in this case is a representative sample of the entire site, eliminates cell-to-cell variability, and leads to increased precision in estimating the mean concentration of the site. If there is a need to estimate the cell-to-cell variability, then the approach in Fig. 2 is suitable. In addition, if the precision of estimating the mean concentration of the cell is needed, multiple composite samples should be collected from that cell.

6.6 *Effect on Cost Reduction*—Because the composite samples yield a more precise mean estimate than the same number of individual samples, there is the potential for substantial cost saving. Given the higher precision associated with composite samples, the number of composite samples required to achieve a specified precision is smaller than that required for individual samples. This cost saving opportunity is especially pronounced when the cost of sample analysis is high relative to the cost of sampling, compositing, and analyzing.

6.7 *Hot Container/Hot Spot Identification and Retesting Schemes*—Samples can be combined to determine whether an individual sample exceeds a specified limit as long as the action limit is relatively high compared with the actual detection limit and the average sample concentration. Depending on the difficulty and probability of having to resample, it may be desirable to retain a split of the discrete samples for possible analysis depending on the analytical results from the composite sample.

1	2	4	3
4	3	2	1
4	2	1	4
3	1	2	3

FIG. 1 Example of Composing Across a Site

1	1	2	2
1	1	2	2
3	3	4	4
3	3	4	4

FIG. 2 Example of Within Cell Compositing

6.8 *Example 3*—One hundred drums are to be examined to determine whether the concentration of PCBs exceeds 50 mg/kg. Assume the detection limit is 5 mg/kg and most drums have non-detectable levels. Compositing samples from ten drums for analysis would permit determining that none of the drums in the composite exceed 50 mg/kg as long as the concentration of the composite is < 5 mg/kg. If the detected concentration is > 5 mg/kg, one or more drums may exceed 50 mg/kg and additional analyses of the individual drums are required to identify any hot drum(s). The maximum number of samples that can theoretically be composited and still detect a hot sample is the limit of concern divided by the actual detection limit (for example, $50 \text{ mg/kg} \div 5 \text{ mg/kg} = 10$).

6.9 *Example 4*—Assume background levels of dioxin are non detectable, and the analytical detection limit is $1 \mu\text{g/kg}$ and the action level is $50 \mu\text{g/kg}$. The site is systematically gridded (the most efficient sampling design for detecting randomly distributed hot spots) using an appropriate design, and cores to a depth of 10 cm are collected. Composite samples are collected since analytical costs for dioxin are high. In theory, groups of up to 50 samples could be composited and if the resultant concentration were $< 1 \mu\text{g/kg}$, all samples represented in the composite should be below $50 \mu\text{g/kg}$. If the contaminant concentration is $> 1 \mu\text{g/kg}$, one or more spots may exist that exceed $50 \mu\text{g/kg}$ in the area covered by the composite sample although the precise location and areal extent would not be known without further sampling and analyses. Compositing fewer samples would probably be more practical, however.

6.9.1 The relative efficiency of compositing individual samples to detect a hot spot depends on the probability of a "hot" discrete sample being used to form a composite sample. According to Garner et al. (1), if the probability can be estimated as low, say 1 %, the optimum number of samples to composite is about ten, which would result in a cost saving of about 80 % (assuming there is no detection limit problem). When the probability of collecting a sample from a hot spot rises to 10 %, the optimal number of samples to composite is 4, which results in a 40 % cost savings. By the time the probability of sampling a hot spot rises to 40 %, there is no cost benefit to compositing. Other resampling and testing schemes are possible and may lead to somewhat different cost saving potentials.

7. Limitations of Composite Sampling

7.1 The principal limitations of sample compositing involve the loss of the discrete information contained in a single sample and the potential for dilution of the contaminants in a sample with uncontaminated material; however,

in that case, the dilution factor can be used to estimate the maximum number of samples that can be composited. The following situations may not lend themselves to cost-effective sample compositing:

7.1.1 When the integrity of individual sample values change because of compositing, for example, chemical interaction occurs between constituents in the samples being combined or volatiles are lost during mixing,

7.1.2 Where the composite sample cannot be properly mixed and subsampled or the whole composite sample cannot be analyzed,

7.1.3 When the goal is to detect hotspots and a large proportion of the samples are expected to test positive for an attribute, compositing and retesting schemes may not be cost effective,

7.1.4 When analytical costs are low relative to sampling costs (for example, in situ field portable X-ray fluorescence takes only 30 s with no sample preparation so analytical costs/sample are very low), and

7.1.5 When regulations specify that a grab sample must be collected (usually a composite sample covering a limited area is still preferred from a technical standpoint).

8. Sample Mixing Procedures

8.1 Prior to sample mixing, project-specific instructions should be followed regarding sample collection, which may include removal of extraneous sample materials such as twigs, grass, rocks, etc. If samples are sieved or large materials are removed, it may be necessary to record the mass of materials removed for later estimation of contaminant concentration in the original sample. According to particulate sampling theory (4,5) the following sample masses are adequate to represent the corresponding maximum size particles in the sample with a relative standard deviation of 15 %.

Sample Mass, g	Maximum Particle Size, cm
5	0.170
50	0.37
100	0.46
500	0.79
1000	1.0
5000	1.7

8.1.1 Frequently it is necessary to mix an individual or composite sample and obtain a representative subsample(s) for transport to the analytical laboratory. This occurs when multiple containers of the identical material are desired (for example, separate sample jars for metals, semivolatile organics, etc. are desired) or when the original sample (or composite sample) size is greater than accepted by the laboratory. Even when the original sample volume is acceptable, it may be desirable to thoroughly mix the sample prior to transport to an analytical laboratory. However, some samples that have been well mixed in the field may segregate during shipment to the laboratory.

8.1.2 A laboratory typically collects a 0.5 to 30 g specimen (100 g for some extraction tests) from the sample for analysis. Specimens are frequently collected from the surface material in the container or after minimal mixing. Such procedures are inadequate to obtain a small representative specimen from a 100 to 300 g sample. Special mixing and subsampling procedures are necessary to obtain a representative subsample unless the sample is already homogenous.

Field mixing should be considered essential unless it is known that the sample in the container is homogeneous or it is known that the laboratory will homogenize the sample and collect a representative specimen. To help ensure that an unbiased and precise specimen is collected, the analytical laboratory should be provided instructions (preferably with the sample shipment) on homogenizing and obtaining a specimen for analysis. Few laboratories follow good sample homogenizing and specimen collection practices. To meet both sampling and analytical objectives, field and analytical personnel, and the end-user of the data must be aware of the laboratories standard practices for handling, mixing, and obtaining a specimen or specify such practices with the sample shipment.

8.1.3 To avoid subsampling it may be possible to collect a small sample (or composite samples) directly into the sample container that is delivered to the laboratory (Caution: small sample sizes may result in bias by excluding large particles). While no field mixing and subsampling is needed as long as the laboratory homogenizes the sample, it may be advisable to mix such samples anyway (see 8.1.2).

8.1.4 Soil, sediment, sludge and waste samples collected for purgeable/volatile organic compounds' analyses should *not* be mixed and subsampled using procedures described in this guide but other specialized procedures such as combining samples directly into methanol (see Practice D 4547) may be appropriate.

8.1.5 A significant problem with analyzing very small samples is that the smaller the volume of sample actually extracted or analyzed, the less representative that sample may be unless thoroughly mixed/homogenized and subsampled. Therefore, sample compositing without thorough mixing can nullify the potential benefits of compositing.

8.1.6 Methods that may be applicable to field mixing, depending on the matrix, include hand mixing in a pan, sieving, particle size reduction, kneading, etc. For highly heterogeneous waste such as municipal refuse, field comminution (grinding) may be needed. Some of these methods may be inappropriate if trace levels of contamination are a primary concern. The use of disposable equipment for mixing should be considered to minimize field decontamination problems. Field personnel should use care to ensure that samples do not become contaminated during the sampling, mixing and subsampling process.

8.1.7 Once a sample has been collected, it may have to be split into separate containers for different analyses. A true split of soil, sediment, or sludge samples may be difficult to accomplish under field conditions.

8.1.8 The following are some common methods for mixing soils, sludges, etc. While it is not always possible to determine that a sample is adequately mixed, following standard procedures and observing sample texture, color, and particle distribution are practical methods. While some materials cannot be homogenized, following the subsampling procedures in Section 9 will help ensure that a representative subsample is collected. Under certain conditions, some of the procedures that follow are applicable when trace level contaminants are of concern.

8.1.8.1 *Pan Mixing/Quartering*—One common method of mixing is referred to as quartering. Place the material in a glass or stainless steel sample pan and divide into quarters.

Mix each quarter separately, then mix all quarters into the center of the pan. Repeat this procedure several times until the sample is adequately mixed (usually a minimum of three repetitions). If round bowls are used for sample mixing, adequate mixing is achieved by stirring the material in a circular fashion and occasionally turning the material over.

8.1.8.2 Mixing Square—Combine samples through a non-contaminating screen into an appropriate clean mixing container. Mix in the container and pour onto a 1 metre square of non-contaminating material such as plastic for metals analyses or polytetrafluoroethylene for organics. Roll the sample backward and forward on the sheet while alternately lifting and releasing opposite side corners of the sheet. This is appropriate for flowable granular materials (6). If polytetrafluoroethylene sheeting is used, this procedure could be acceptable for trace level contaminants.

8.1.8.3 Kneading—Place the sample in a non-contaminating bag and knead as in bread making to mix the sample. This may be appropriate for viscous or clay-like materials. If a non-contaminating bag is used, this approach would be acceptable for trace level contaminants.

8.1.8.4 Sieving and Mixing—If a laboratory requires a small specimen (1 to 30 g) or if less than a specific particle size is required, disruption of aggregated particles or sieving, or both, followed by mixing may be needed. Sieving allows only those particles below a desired size to pass through the sieve into a mixing pan for subsequent mixing and subsampling into containers. Sieving works best with relatively dry granular materials. Sieving and the exclusion of large particles can result in very biased results and should only be conducted when designed into a sampling plan.

8.1.8.5 Particle Size Reduction—When particle size reduction is appropriate and trace contaminants are of concern, non-contaminating materials compatible with objectives should be used (for example, glass, ceramic, stainless steel). Other materials may be acceptable if trace levels of contaminants are not a concern. The reduction method can be as simple as using a hammer to break apart large pieces into smaller pieces that are either acceptable to the labora-

tory or that can pass through a sieve. This method of reduction creates a great deal of fine material which may or may not be included in the sample container, and could introduce bias. More complex reducers, such as ball mills, ceramic plate grinders, etc., are available, but usually require relatively dry samples and thorough decontamination to avoid cross contamination. Such a process may be more appropriately conducted in a laboratory.

8.1.9 With thorough decontamination (see Practice D 5088) of the particle size reducer, sieve and the mixing pan, these procedures could be acceptable for trace level contaminants.

8.1.10 Other Mixing Equipment—Riffle splitters, coning and quartering, etc., involve equipment and materials that are difficult to decontaminate, and awkward to use on a routine basis for waste management sampling. Since these procedures are not routinely used, the devices are not considered in this guide. However, procedures for coning and quartering, and the use of riffle splitters are described in Practice C 702 and could be modified for subsampling contaminated media.

9. Field Subsampling Procedures

9.1 If mixing procedures could ensure a truly homogeneous sample, subsampling would be simple. Mixing of various particle sizes may, however, cause the particles to segregate according to size, and improper subsampling could introduce bias. Since homogeneity is frequently not achieved, appropriate subsampling procedures should be used by field personnel to provide representative subsamples. The procedures that follow are appropriate for collecting a representative sample from a larger sample. As noted previously, riffle splitters and coning and quartering procedures can also be used for subsampling as well as mixing (see Practice C 702).

9.1.1 Rectangular Scoop—As the final step of mixing, the material is arranged in a pile along the long axis of the rectangular pan. A flat bottomed scoop with vertical sides is moved across the entire width of the short axis of the pile to collect a swath of sample (Fig. 3). Multiple evenly-spaced

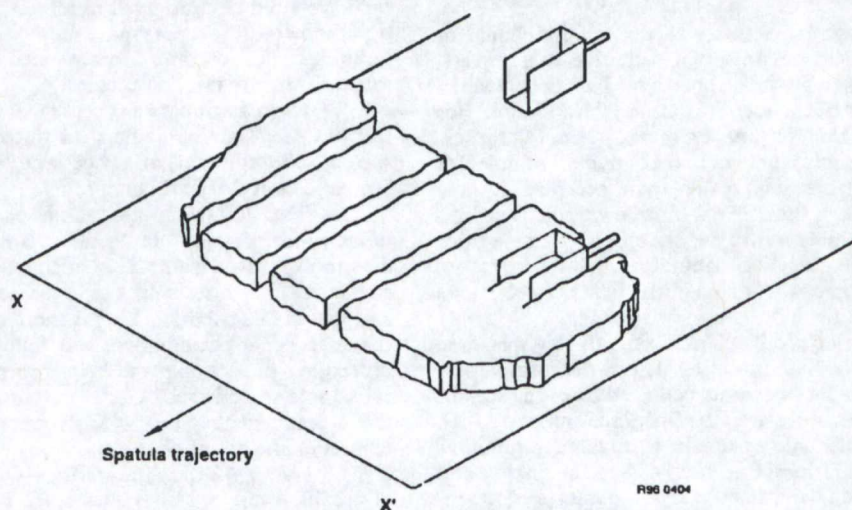
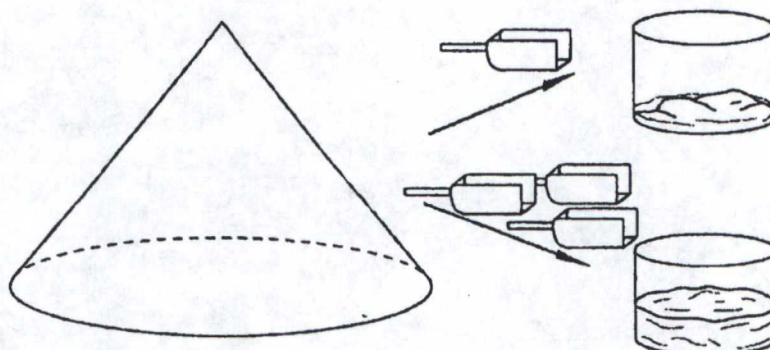
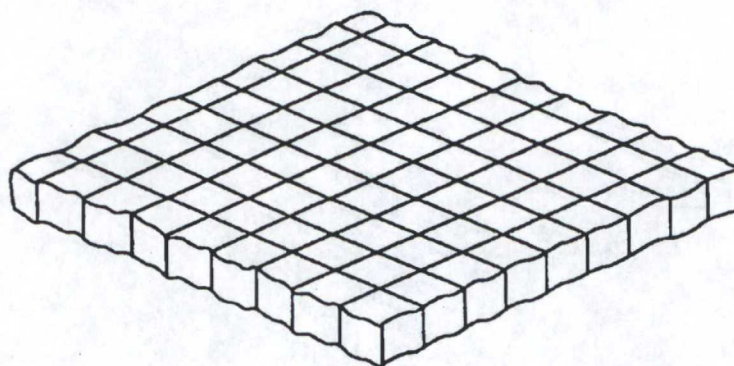


FIG. 3 Rectangular Scoop as Used to Collect Swaths for Subsample



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FIG. 4 Alternate Scoop Subsampling Technique



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FIG. 5 Slab Cake Subsampling Technique

swaths are collected until the subsample container is full. Multiple containers are filled by rearranging the remaining material and collecting swaths as just described.

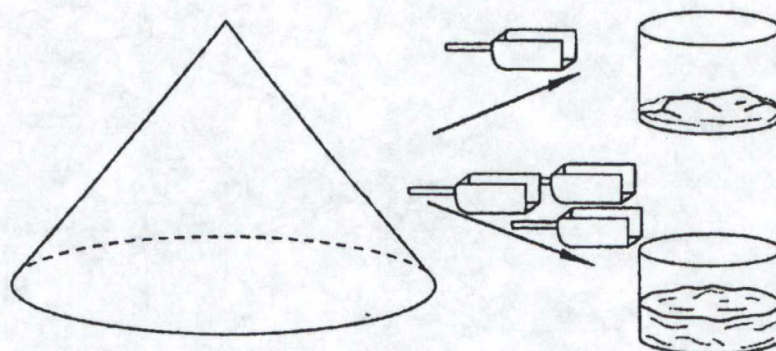
9.1.2 Alternate Scoop—The volume of material required for filling sample containers is compared to the volume of the mixed sample. Scoops of mixed material are placed in the sample container(s) or are discarded, that is, three scoops are discarded for every scoop saved when collecting a 25 % subsample (Fig. 4). Care should be taken that each scoop of material is of the same size and is collected in a consistent manner to minimize bias (5).

9.1.3 Slab-cake—The cohesive or clay-like materials as

discussed in 8.1.8.3 on kneading. The sample can be flattened, cut into cubes (Fig. 5) and the cubes randomly or systematically combined into subsample(s) (5). The subsample should be re-kneaded before shipment to the laboratory unless it can be ensured that the laboratory will homogenize the subsample before collecting a specimen.

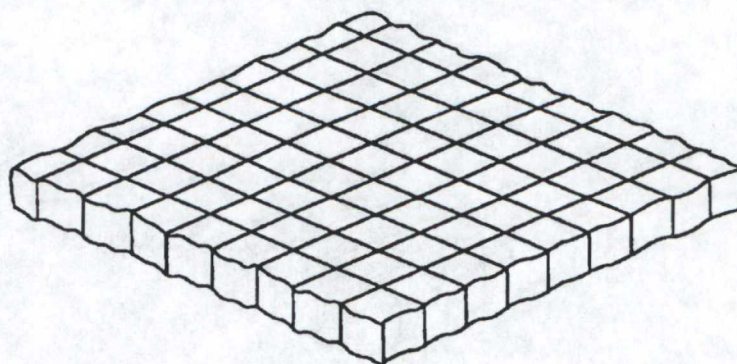
10. Keywords

10.1 composite; compositing; hot spot; particle size reduction; sample; sampling; subsample; subsampling



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